FOREST PRODUCTS JOURNAL

FOREST PRODUCTS RESEARCH SOCIETY

Exposure tests of acrylic emulsion paints on wood panels. See page 1.

FEATURED THIS ISSUE →

Acrylic Emulsion Paints for Exterior Woodwork

Seasoning Wood Carvings with Polyethylene Glycol

Linear Programming—Top Production and Profit

Bark and Sawdust Mulches

Fumigants Kill Oak-Wilt Fungus in Wood

Douglas-Fir Permeability

How to Analyze Charcoal for Consumer Acceptance

Flakeboard Properties vs. Resin Efficiency

Plus: Three Articles on Wood Preservation

Vol. XI, No. 1

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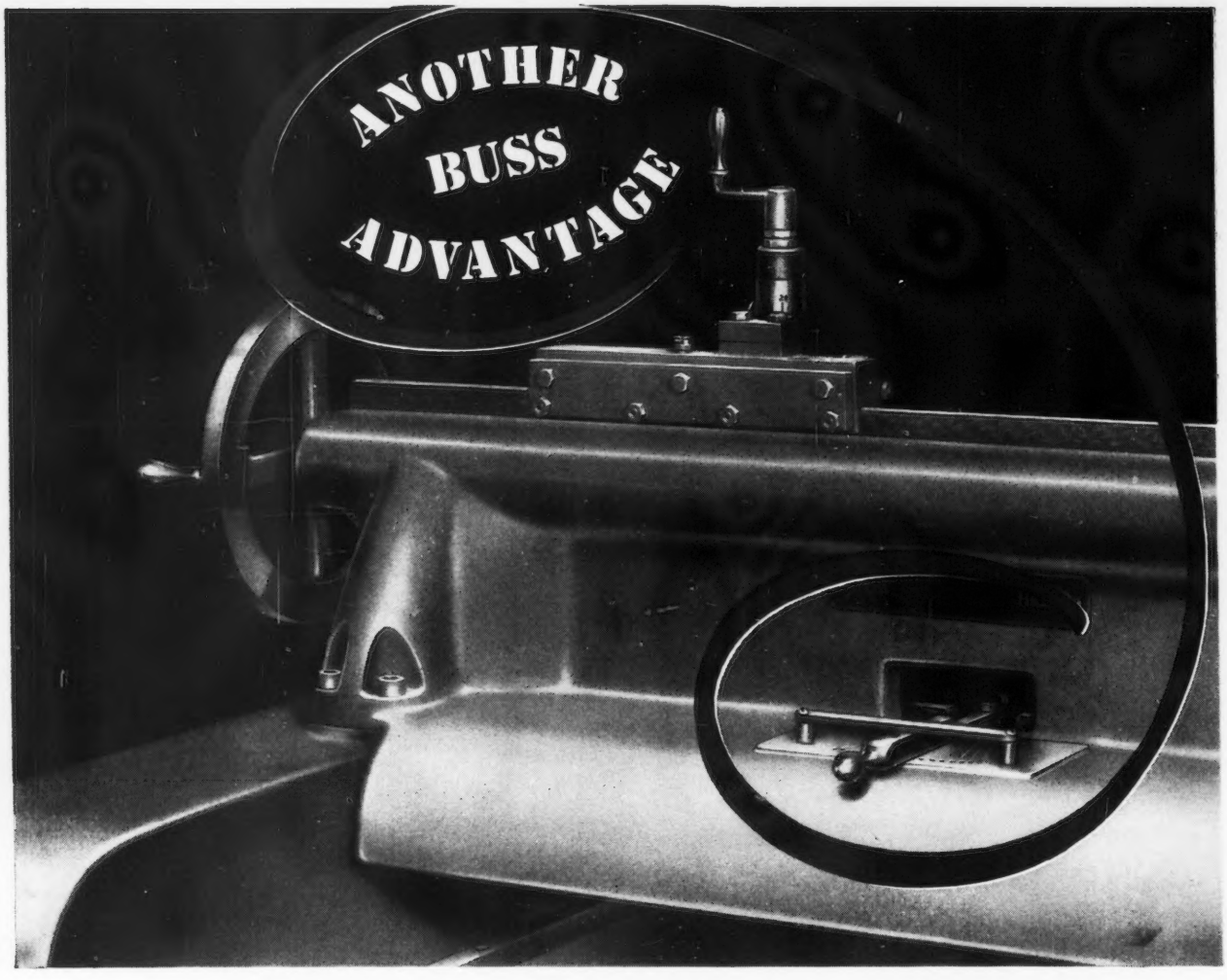

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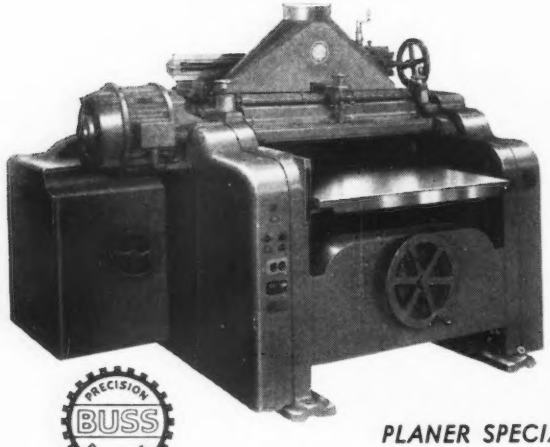

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FOREST PRODUCTS JOURNAL

Vol. XI, No. 1 January, 1961

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FPRS News-Digest

FOR YOUR CONVENIENCE

We've added a Reader Service Form. For more information, circle appropriate item on page 48. We'll do the rest.

A Message from the President

. . . Raymond H. Berry

THIS IS THE AGE OF COMMUNICATION, we are daily informed—mass communication, instantaneous communication, perhaps soon interplanetary or even interstellar communication. But it sometimes seems that the more we communicate, the less we succeed in completing the circuit—the meeting of human minds with regard to a concept which they comprehend. The Forest Products Research Society is basically a communications group, designed for the communication of ideas, of research based on those ideas, and of physical applications of that research, among a group of people with diverse occupations but with a unifying interest in wood and its uses by mankind.

As the specialization of individual interests and occupations increases, it becomes more and more difficult not only for the practitioner of one art or science to communicate with those in other specialized fields, but also for those within the circumference of one general interest to communicate with others in that field. In our own field of wood, there is such diversity of approach that even here complete communication has become difficult. In our FOREST PRODUCTS JOURNAL we have a vehicle of communication that can be used to the utmost advantage of all individuals who are concerned with the future of one of our greatest natural resources as well as with its complete utilization for the benefit of producers and consumers.

To that end, the Executive Board of FPRS, its Publications Committee, the editorial staff of the JOURNAL, and the National Office have been giving prolonged and, it is hoped, fruitful consideration to the format and content of the magazine. Our FOREST PRODUCTS JOURNAL should by all means continue to perform its primary function of publishing reports of research, both basic and applied, in the field of wood. In addition, it should be a means of intercommunication within the Society and give the members live and up-to-date news concerning the activities of FPRS Sections, Divisions and Committees, and worthwhile news about the members themselves. Through the JOURNAL we should know what is going on throughout the Society and, if necessary, discuss at intervals matters of interest to the diverse groups of which it is composed. In this way, we will bind together within our Society, by complete communication, the wood technologists, the manufacturers who make practical application of the technologists' discoveries, the suppliers who ingeniously devise new machines and substances, the foresters who are concerned with our raw material, the academic authorities who train both the technologists and the foresters, and the students in the various fields who go on to take up the work now in progress.

Our Society, with no regional bias and no fiscal or commercial axes to grind, has an unequalled chance to assume leadership in the advances made in the wood field. To do this, we must be able to talk to each other and to comprehend what is being said. The one indispensable medium for that kind of communication is the FOREST PRODUCTS JOURNAL, and it is our fervent hope that by the promulgation of a broad and generally interesting editorial policy for the magazine, that communication will be achieved.

John McDonald, Editor, *Forest Products Journal*, and Dr. H. O. Fleischer, Chairman, Publications Committee, discuss value of FPRS Proceedings.

Pay Postage, Handling Only On 1947–51 FPRS Proceedings

The Executive Board recently authorized the National Office to make available to members complete sets of the 1947-51 FPRS Proceedings for the cost of postage and handling alone. The five cloth-bound volumes, which contain all published National Meeting papers of those years, constitute a general cross section of modern wood technology.

Complete sets will be mailed postpaid to any part of the United States for $3.00, anywhere else in the world for $5.00.

According to Dr. H. O. Fleischer, Chairman of the FPRS Publication Committee, students doing graduate work and senior technologists alike have found these volumes a valuable reference tool at the U. S. Forest Products Laboratory.

"Many faculty members of colleges and universities that offer degrees in wood technology consider the FPRS Proceedings extremely valuable as supplemental texts. They are a must-item for any industrial organization or any educational institution that wants to maintain a complete and balanced library of modern forest products technology," Dr. Fleischer concluded.

At the Executive Board Meeting which authorized this offer, President R. H. Berry described the proceedings as the "technical backbone of the Forest Products Research Society," and suggested that each Section might well consider the possibility of donating one or more sets of the Proceedings to each wood technology school in their area.

"Who knows how many 'million dollar ideas' are yet to be found in these pages—or how many methods and techniques, developed years ago, that now need only simple modification to be the exact solution for a present day problem," President Berry said.

For additional details see the new Reader Service Form on last page.

See Reader Service Form, page 48.

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The National Office of the Forest Products Research Society wishes to commend all those members who, being no longer eligible for Student Memberships, have voluntarily applied for regular Voting Memberships. As the Society occasionally neglects to determine whether or not its Student Members are still in school, we appreciate the honesty shown by these young men . . . future leaders of this industry.

Varied Program Featured At PNW Meeting

The Annual Meeting of the Pacific Northwest Section is scheduled for February 6 and 7, in Portalnd, Ore. at the Multnomah Hotel. The technical program for the meeting will include papers on pith vs. geometric center for block chucking, 3-ply vs. 5-ply one-half inch plywood, high speed-high temperature veneer drying, gluing characteristics of little used species, and the pros and cons of standardization and certification of hardboard and particle board.

There will be field trips to the ultra-modern Waterways Terminal with the latest in automatic and efficient materials handling equipment; Crown Zellerbach's Camas mill and research facilities; Portland's Exposition–Recreation Center; and the Lloyd Center, the world's largest shoping center.

Mark Lehrbas Retires From Forest Service

Mark M. Lehrbas, Chief of the Division of Forest Utilization, Southern Forest Experiment Station, retired from the U. S. Forest Service October 31. He completed over 32 years of forestry work in the U. S. Department of Agriculture. His retirement was announced by Philip A. Briegleb, Director of the Southern Station.

Lehrbas received a Bachelor of Science Degree in Forestry from the University of Idaho in 1927, and began his career with the Forest Service in 1928 as Junior Forester on the Ouachita National Forest, joining the Southern Station in 1931. Transfers took him to offices and projects in Atlanta and Waynesboro, Georgia, Tallahassee, Florida, and finally, back to New Orleans in 1945. He has been Division Chief since 1950.

Lehrbas' primary interest has been in machinery and techniques used in sawmill and pulpmill operations, wood preservation, drying kilns, and utilization of sawmill residues. He has worked closely with leaders of forest industry across the South to stimulate the application of new processes and machines to southern pine and hardwoods and has written numerous articles, mostly about new products and methods of the wood industries.

Seasoning Course Given At Research Center

Twenty-one kiln operators from five western states attended a 6-day course in lumber seasoning held November 28 to December 3 at the Oregon Forest Research Center, Corvallis. Classes in all phases of drying of wood were presented by instructors from the Research Center and the Oregon State College School of Forestry. A. C. Knauss, kiln-drying consultant and formerly with U. S. Forest Service, also instructed classes.

This was the 12th course in lumber seasoning presented through the cooperation of the Research Center, OSC School of Forestry Pacific Northwest Forest and Range Experiment Station, and the U. S. Forest Products Laboratory, Madison, Wisconsin.

Fire Tests Methods Symposium Planned

ASTM Committee E–5 on Fire Tests of Materials and Construction is sponsoring a Symposium on Wednesday, February 1, 1961 on Fire Tests Methods, as part of the ASTM Committee Week meeting, January 30–February 3, in Cincinnati. The Symposium will be presented in an afternoon session starting at 2 p.m. Mr. A. F. Robertson, of the National Bureau of Standards, will preside. The following papers will be presented: Early History of Fire Endurance Testing in the United States by Harry Shoub, National Bureau of Standards; A Treatise on Theoretical Fire Endurance Rating by T. Z. Harmathy, National Research Council of Canada; The New Beam Furnace at PCA and Some Experience Gained from Its Use by C. C. Carlson and P. J. Tatman, Portland Cement Assn.; Surface Flammability of Materials—A survey of Test Methods and Comparison of Results by J. A. Wilson, Factory Mutual Engineering Division.

G. H. Chidester Receives Two High Honors

The National Academy of Sciences—National Research Council announced recently the appointment of Mr. Gardner H. Chidester, Chief of the Division of Pulp and Paper at the U.S. Forest Products Laboratory, Madison, Wisconsin, as a member of the Academy—Research Council's Committee on Paper Base Materials. Mr. Chidester's special interest has been the development of new techniques for preparing wood pulps.

The Committee is one of several within an Advisory Board on Quartermaster Research and Development. The Advisory Board is responsible for supplying scientific and technical advice to the Quartermaster Research and Engineering Command, Natick, Massachusetts, on the Command's research and development programs.

Mr. Chidester also has recently been honored by being selected as the recipient of the 1961 TAPPI Gold Medal. The presentation of this award will take place during the banquet at the annual meeting in February.

 See Reader Service Form, page 48.

FHA Issues Bulletin On Particleboard

Particleboard which conforms to a new Use of Materials Bulletin covering particleboard for floor underlayment, issued on November 16, 1960, by the Federal Housing Administration, is now accepted by that agency, according to an announcement by D. C. Greeley, of the Weyerhaeuser Company, President of the National Particleboard Association.

The acceptance was made official in the Federal Housing Administration's "Use of Materials" Bulletin, No. UM–28, released November 14, 1960, under the title, "Mat-Formed Wood Particleboard for Floor Underlayment." The Association's standard for floor underlayment is incorporated in that Bulletin.

Short Course Offered To Lumbermen

The twelfth annual Lumbermen's Short Course will be held on the St. Paul Campus of the University of Minnesota Feb. 6–17, it was announced recently by J. O. Christianson, Director of Agricultural Short Courses at the Universtiy.

Eligible to enroll are lumber dealers, yard employees and people interested in the building material supply industry. Enrollment is limited to 45 students, according to Louis W. Rees, professor of forestry, who is program chairman.

The course is offered in cooperation with the Hoo Hoo Clubs, Midwest Lumber Dealers' Association and Northwestern Lumbermens' Association. Instructors will be University of Minnesota staff and industry members. Classes will be held on the St. Paul Campus.

Subjects will include: blueprint reading, building cost estimating, farm structures, home remodeling, farm building ventilation, lumber properties, insulation, wood preservation, advertising, accounting statement analysis, credits and collections, salesmanship, installment selling, business law, business letters, public speaking, F.H.A. regulations, lumber yard management, lumber handling and storage. A field trip to a millwork plant is also planned. Arrangements for enrollment may be made by contacting the Short Course Office, Institute of Agriculture, University of Minnesota, St. Paul 1.

Plywood Industry Adopts Commercial Standard

A new commercial standard for Douglas fir plywood, expanded in some areas to take advantage of recent scientific advances and revised in others to clarify meanings, has been put into effect. Industry spokesmen said the new standard, completely reworked for the first time since 1955, applies to all fir plywood produced since November 14.

The Commodity Standards Division of the U. S. Department of Commerce promulgated the standard after its acceptance by all segments of the industry. The standard is designated CS 45–60. Special reprints carrying facsimiles of DFPA grade-trademarks are available free from Douglas Fir Plywood Association, 1119 A Street, Tacoma 2, Washington.

Logging Safety Program Presented at OSC

Speakers for the first Oregon Logging Safety Institute to be held at Oregon State College, Feb. 9 and 10, 1961, have been announced by the Pacific Northwest Loggers Association and the College.

All of the speakers for the 2-day management institute are woods safety specialists from large and small logging companies. The program has been divided into 4 half-day sessions to allow ample time for questions and discussions.

Moderators and session subjects are: "The Need for Accident Prevention," R. P. Miller, safety director for International Paper Company, Longview, Wash.; "The Causes and Cures of Woods Accidents," K. L. Gipson, safety director, Georgia–Pacific, Portland; Open Forum Safety Discussion, L. L. Stewart, president of Bohemia Lumber Company, Eugene, Ore.; "The How of Accident Prevention," L. B. Hoelscher, safety director, Weyerhaeuser Company, Tacoma, Wash.

Purdue Site of Co-op Kiln-Drying Courses

The Fourth Annual Cooperative Kiln-Drying Short Course will be held February 27 to March 3 at Purdue University, Lafayette, Indiana, according to an announcement by Michael O. Hunt, Extension Specialist in Wood Utilization at Purdue. The Short Course will be conducted cooperatively with the following agencies: Delmhorst Instrument Company, Foxboro Company, Iowa State University, Lumber Drying Speciality Company, Michigan State University, Moore Dry Kiln Company, University of Illinois, Standard Dry Kiln Company, Southern Illinois University, University of Michigan, Wel-Dri Company, and Fan-Air Systems, Inc.

Major emphasis of the 5-day course is placed on the practical aspects of seasoning. Participants are especially urged to bring specific problems for consideration during special discussion periods. For further information about the short course, write: Michael O. Hunt, Department of Forestry and Conservation, Purdue University, Lafayette, Indiana.

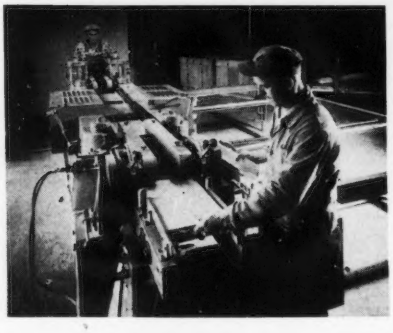
Oregon State Plans Safety Institute

Program plans for the first Oregon Logging Safety Institute to be held at Oregon State College Feb. 9 and 10, 1961 have been announced by the Pacific Northwest Loggers Association and the college.

The two-day management institute has been designed to give the small logger the latest up-to-the-minute information on modern techniques of logging accident prevention. Discussion leaders, representing industrial accident commissions, industrial accident insurance companies, and loggers both large and small, will keep the tempo of the meetings geared to experience and information exchange.

Registration forms will be mailed to most Oregon loggers by Jan. 10, 1961. Additional information or registration blanks may be obtained by writing the OSC School of Forestry, Corvallis, Oregon.

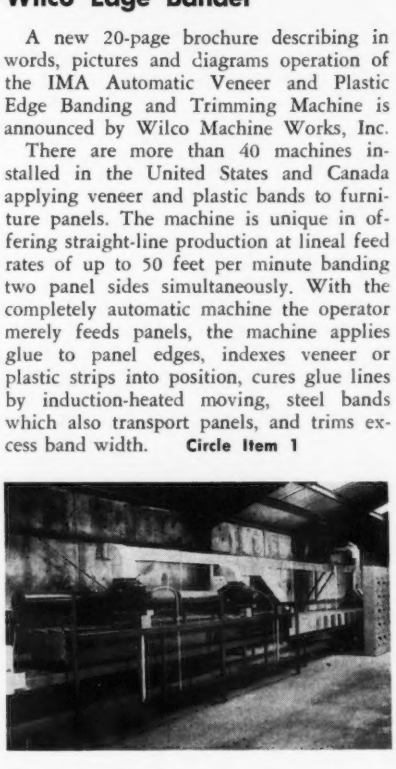
NEW PRODUCTS and Literature



Wilco Edge Bander

A new 20-page brochure describing in words, pictures and diagrams operation of the IMA Automatic Veneer and Plastic Edge Banding and Trimming Machine is announced by Wilco Machine Works, Inc.

There are more than 40 machines installed in the United States and Canada applying veneer and plastic bands to furniture panels. The machine is unique in offering straight-line production at lineal feed rates of up to 50 feet per minute banding two panel sides simultaneously. With the completely automatic machine the operator merely feeds panels, the machine applies glue to panel edges, indexes veneer or plastic strips into position, cures glue lines by induction-heated moving, steel bands which also transport panels, and trims excess band width. **Circle Item 1**



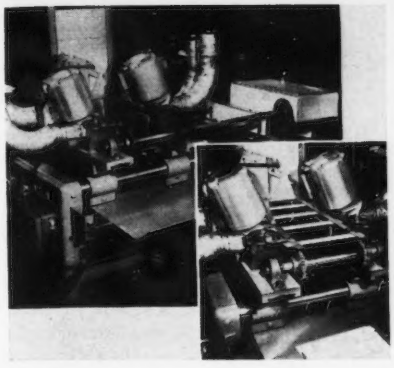
Grenco To Represent DriQuik Ovens

Grenco, Inc., Portland, Ore., headed by H. John Knapp, has been appointed the west coast representative for DriQuik ceramic type electric infra-red ovens. This announcement was made by M. N. Kanouse, President of the Dry Clime Lamp Corp., of Greensburg, Ind., manufacturers of DriQuik ovens.

Mr. Knapp is well known in the metal and wood finishing fields. He also represents several other leading manufacturers of finishing equipment.

Mr. Knapp recently set up at Long Beach, Calif., a complete finishing line with all types of finishing equipment then installed for research purposes. The main use of this installation is to provide complete testing service for west coast manufacturers as well as for metal and wood finish suppliers: **Circle Item 2**

See Reader Service Form, page 48.



Pistorius Develops Machine For Assembling Louvers

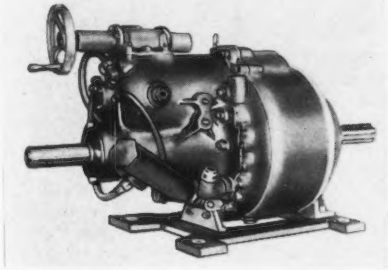
Pistorius Machine Co., Inc., L. I., N. Y. has developed a precision-engineered machine that revolutionizes the assembly of wooden louvers for shutters, doors and screens.

The new equipment features a magazine feed which will accommodate a ¾-inch stock length variation. Four cutting heads (automatically processing any hardness of wood) saw each louver to a uniform length and simultaneously cut the ends to "vee" edges. Additional roll forming wheels round the remaining corners, to produce completely ideal beveled ends. As a result, successful automatic assembly operations may now be employed.

An easy-loading hopper, coupled with smooth high-speed endless chain drive feed, delivers a minimum rate of 120 louvers per minute. Assembly is quickly handled with simple jigs on a clamp table.

Technical data and price information on this and other shutter equipment is available in Bulletin 1841 on request.

Circle Item 3



New Hydraulic Transmission

The 10-HP variable speed hydraulic transmission permits low cost automation and modernization of existing machinery—as well as development of new equipment to increase production and save money.

Provides infinitely variable speeds from duty applications as: woodworking ma- 0–to–1600 RPM for high-torque, heavy- chines; machine tool drives; conveyors; lifts and hoists; elevators; bailing presses; sawmill machinery; chip and dust collectors; compressors; blowers and experimental and labor work.

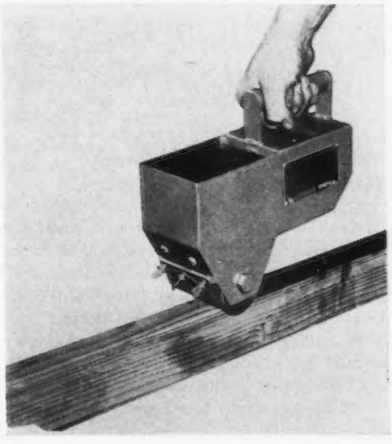
The machine drives at 1800 RPM or less with any 2 to 10 HP motor or 20 HP gas engine. Precise speed selection is obtained by rotation of hand wheel giving infiite number of speeds through entire range of unit. **Circle Item 4**

Polymer Plant Produces Resyn 3600

National Starch and Chemical Corporation's 14 million pound polyvinylidene chloride resin plant at Meredosia, Illinois is now "on stream". S. F. Thune, Vice President, today announced that the company's new facility is in commercial production of Resyn 3600, an aqueous dispersion of vinylidene chloride copolymer.

Resyn 3600 offers exciting possibilities for packaging, surface coating, and construction material, due to its extremely low water vapor transmission rate, its barrier properties which resist the permeation of organic vapors and gases such as oxygen, nitrogen and carbon dioxide, as well as its exceptional chemical, grease and oil resistance properties.

Informative literature, data and test material may be obtained through any of National's sales offices or its executive offices, 750 Third Avenue, New York 17, New York. **Circle Item 5**



Portable Glue Spreader

Black Bros. new Portable Hand Operated Glue Spreader is suitable for numerous gluing operations. Its speed, accuracy, cleanliness and economy are readily apparent over other means of manually applying adhesives.

The spreader is equipped with a 3½ inch long gluing roll, but as shown in the above photograph, can also be used on narrow edges without "run over." It weighs slightly under 7 pounds, and holds approximately 2 quarts of adhesive. As illustrated, there are 3 thumb screws for adjusting the spring steel scraper to control the amount of adhesive applied. The unit can be readily cleaned without disassembly.

A uniform glue film of approximately 60 pounds per thousand square feet of glue line of either casein or resorcinal adhesive can be applied with the proper roll grooving. Due to the difference in the viscosity of these two adhesives, the gluing roll should preferrably be grooved for the particular adhesive to be used, rather than with a general purpose grooving. If there is considerable production with both adhesives, two spreaders would be desirable. If only one of these adhesives is used occasionally, an extra gluing roll, grooved appropriately, may be purchased.

Circle Item 6

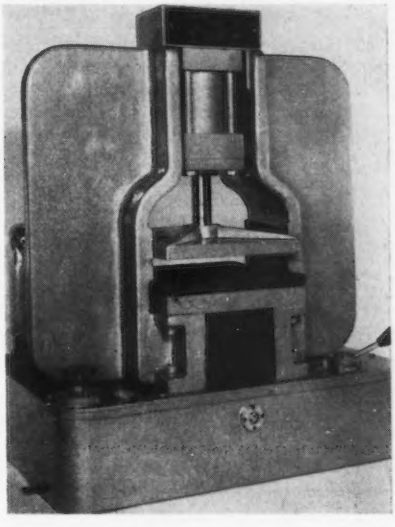
Walnut Gifts Labelled

A new pressure-sentitive label is being made available to authorized manufacturers for use on gift and novelty items made of authentic walnut wood, the American Walnut Manufacturers Association reports.

The label, deep brown in color and embossed in gold, identifies the item as either "Solid American Walnut" or "Genuine American Walnut." The "solid walnut" seal is reserved for articles fashioned from solid walnut lumber; the "genuine walnut" identification is for items made of walnut veneers or a combination of walnut solids and veneers.

The seals are available at cost from the association. To obtain them, the users must agree in writing that they will be applied only to items which meet the specifications. Manufacturers may obtain further information about the seals from the American Walnut Manufacturers Association, 666 N. Lake Shore Drive, Chicago 11, Illinois.

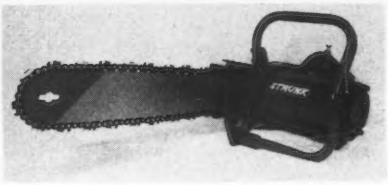
Circle Item 7



Alfa Laboratory Cutter

Thwing-Albert Instrument Company announces the development of a new electro-hydraulically operated laboratory sample cutter. The Model #240–4 Alfa Laboratory Sample Cutter, more powerful than hand operated models, is adjustable to apply up to 8 tons of pressure at the cutting surface.

Circle Item 8



Electric Chain Saw

An electric chain saw built to cut wood comparable with the most powerful models of gasoline chain saws has been developed by Strunk Power for Modern Living, Inc., Coatesville, Pennsylvania, manufacturers of chain saws, portable pumps, emergency generators and riding mowers.

The saw has many "firsts" in the electric field. It is the highest horsepower motor utilized in a portable electric tool—the motor develops 7 horsepower. All motor parts have been built for over capacity. Commutators, brushes, windings, etc. are designed to withstand higher amperage load than the saw would normally use. There is a centrifugal clutch on the motor which allows for smooth and easy disengagement of the cutting chain and automatically disengages the cutting chain when the motor is brought down to a speed at which it would overheat. Chain cutting speed is higher than any previously utilized in the electric chain saw field and is equal to any found on gasoline saws.

Circle Item 9

Veneer Jointer Offered

A traveling head veneer jointer with hydraulic carriage travel and hydraulic clamp to remove up to 1½ inches of stock in one cut is offered by Ericsson Merritt, Inc., 515 Pine Street, Lockport, New York. The carriage of this machine is designed for three separate cutterhead motors of a rating adequate and balanced for the work each different cutterhead is expected to do. The carriage will accommodate motors up to a maximum of 15 H.P. each.

This machine eliminates a great deal of dry clipping which is normally required preparatory to jointing, thus saving considerable cost. **Circle Item 10**

Booklet Demonstrates Cost-Saving Tricks

A 12-page booklet with ideas for modern, economical one-story school buildings has been prepared by Independent Nail & Packing Company, Bridgewater, Mass., and is available on request to anyone interested.

The booklet, entitled "The Stronghold Line of Nails in Schools," shows cost-saving techniques made possible by the use of Stronghold, Screw-Tite and other improved nails. These nails, in conjunction with the engineered use of wood, provide fastenings which hold permanently tight and result in a fully balanced design in which components and joints are equally strong, thus increasing the life of the structure and decreasing the cost of upkeep. Wood construction, along with combinations of wood, steel and masonry are shown.

The booklet illustrates modern school and auxiliary buildings, and includes detail drawings of the various components, with the proper nail for each. It has been prepared on the basis of the continuing program of scientific laboratory research and testing sponsored by the company over a period of years at Wood Research Laboratory, Virginia Polytechnic Institute.

Circle Item 11

Color Catalog Offered By Georgia-Pacific

A 1961 forest products catalog in color, actually a series of four color booklets, has just been published by Georgia-Pacific Corp. for free distribution to the trade.

The four sections, available separately or as a group, are:

(1) Decorative Paneling; (2) Siding, Fir Paneling, Sheathing and Combination Subfloor-underlayment; (3) Overlaid and Standard Fir Plywood; (4) Hardboards.

The four, which will be included in the 1961 Sweet's files, may be ordered separately or as a group without charge by dealers, architects, builders, interior decorators, woodworkers and others working with forest products.

Circle Item 12

Weyerhaeuser Releases Ply-Veneer Booklet

The first comprehensive information booklet on Ply-Veneer panels for building has been released by Silvatek Division of Weyerhaeuser Company. Ply-Veneer, a kraft-overlaid-veneer sandwich panel, has been finding an unusual variety of applications as a cost-saving utility panel in both home and commercial building. Among the most important uses have been for wall panelling, ceiling tile backing, room dividers, partitions and screens.

Ply-Veneer is now available in natural kraft surfaces and in a clean white. It can be painted effectively, and worked with ordinary wood-working tools. Working and finishing techniques are described in the new brochure, and plan sheets on numerous building projects are available free.

Circle Item 13

Colored Preservatives

Introduction of two new water repellent preservatives has been announced by Protection Products Manufacturing Company.

Woodlife Brown contains all the same high qualities as Woodlife Clear, known and used by the woodworking industry and consumers for the past 25 years. "Brown" has been added to satisfy the rapidly growing demand for a colored water repellent preservative primarily for use as a stain by consumers, local and state governments for the treatment and protection of buildings, picnic benches, tables, etc.

Woodlife Green contains the well-known copper naphthenate (2 percent metallic copper) as the preservative to meet the increased use of Government Specifications for wood in contact with water, and for special marine use in protecting against wood borers, and attack by marine growths.

Circle Item 14

What's New in Technical Publications

Single Copies of the Following Reports are Available Free Upon Request from the Director, U.S. Forest Products Laboratory, Madison 5, Wis.

Eleven new or revised reports dealing with various phases of research on wood and its related products have been released by the U. S. Forest Products Laboratory, Madison, Wis.

The mathematical equations used to predict some strength properties of laminated beams, utilizing high-quality wood on the outside and a low quality or weaker species in the core, are contained in **Report 2156,** "Stiffness and Bending Strength of Beams Laminated from Two Species of Wood."

In **Report 2199,** "Adhesives, Their Use and Performance in Structural Lumber Products," is a brief discussion of advantages and disadvantages of the three types of adhesives used most in the structural laminating field; namely, casein glue, and resorcinol, and phenol-resorcinol resins.

Two reports describe methods of protecting or preserving wood products from decay fungi. **Report 761,** "The Preservative Treatment and Staining of Shingles," was revised to incorporate recent research findings. In **Report 2201,** "Protecting Bulk-Piled Green Lumber from Fungi by Dip Treatment," is an account of experiments that successfully reduced losses from fungi action in green lumber stored in bulk piles.

More recent information was incorporated into two reports in the Foreign Wood Series; namely, "Marupa," **Report 1956,** describing a tropical American wood, and "Kokrodua," **Report 1978,** which contains data on a species of wood from West Africa.

A technique used in the laboratory to accelerate the weathering of paints for the investigation of the effects of excessive coating thickness is explained in **Report 2203,** "An Attempt to Hasten Test-Fence Studies of Paint Failures Caused by Too-Frequent Repainting."

Basic research findings related to problems in wood seasoning are contained in **Report 2198,** "Interaction of Moisture and Wood."

Two reports, **No. 704,** "List of Publications on Wood Preservation," and **No. RPI–4,** "List of Publications on Structural Sandwich, Plastic Laminates, and Wood-Base Aircraft Components," are publication listings that were revised to include the latest source material.

Information on drying lumber may be found in a report entitled "Approximate Air-Drying and Kiln-Drying Periods for 1-Inch Lumber," Technical Note No. 233 (Rev.)

See Reader Service Form, page 48.

NAMES in the NEWS

Temple

Marts

Dr. Ben S. Bryant has been appointed the new director of the University of Washington Institute of Forest Products. He assumed his new duties after 10 years of teaching, research, product development and consulting activities in the forest products field. **Dr. D. H. Clark** formerly assistant technical director of the Institute of Forest Products, has recently retired and is now a forest products consultant in Seattle.

Latane Temple has been elected to serve as vice president and general manager of Temple Lumber Company, it was announced by **Arthur Temple, Jr.**, president of the company, a supporting member of FPRS.

A 31 year career in research at the U.S. Forest Products Laboratory, Madison, ended recently with the retirement of **Ralph O. Marts,** technologist in the Division of Timber Growth and Utilization. Mr. Marts earned recognition with the development of various techniques in the use of incident-light microscopy and photomicrography, as well as for his work in preparing specimens and photographing the microstructure of wood.

Byrom

Bremhorst

Election of **F. L. Byrom** as president of Koppers Company, Inc. was announced by **F. C. Foy,** chairman of the board, following the meeting of the Directors. Mr. Byrom and **W. P. Arnold,** executive vice president, were also elected to the Board of Directors. Koppers is an FPRS supporting member.

Three appointments have recently been announced by U.S. Plywood Corporation. **R. L. Bremhorst** has been named national merchandising manager for the corporation's patented particle board, Novoply; **K. T. Leonhardt** is now manager of the Harrisburg, Penn., branch; and **J. A. Ball** has succeeded Mr. Leonhardt as hardwoods merchandising manager.

Soderhamn Machine Manufacturing Company announced the addition of two new representatives at its Portland, Ore., sales office. **R. J. Hill** will coordinate engineering and production for the office, and **G. W. Thoming** is sales representative, covering Oregon and Washington.

Verne Ketchum, Director of Engineering of Timber Structures, Inc., Portland, has recently retired. Along with his regular work, Mr. Ketchum has contributed to many engineering texts and has authored dozens of articles for engineering and construction publications. **George Birkemeier,** now heads the engineering department, and **George Culbertson** is assistant chief engineer.

The G. M. Diehl Machine Works, Inc., Wabash, Ind., has named three exclusive representatives for their products. The **Garrison Machinery Co.,** Statesville, N. C., will now cover the entire states of North Carolina and South Carolina, a portion of eastern Tennessee and the southern part of Virginia; **Claude Tyler,** Warsaw, Ind., will cover all of northern Indiana; and the **Burrill Saw & Tool Works,** Ilion, N. Y., will handle the Mohawk Valley.

EMPLOYMENT *Opportunities*

Positions Offered

E-406—Leading Particle Board manufacturer has opening for Production Control Supervisor. Responsibilities would include scheduling machine loading, expediting, shipping, receiving, and stores. Send resume and salary expectd c/o Forest Products Journal. (Jan.)

E-407—Head of Quality Control Dept. which would consist of all in-process inspection on our boat production lines. This department consists of 8 men and is expanding. (Jan.)

E-408—Mill supervisor in wood working mill over 3 assistant foreman and 80 men. (Jan.)

E-409—Highly qualified person in field of production management. University background or degree in wood technology and utilization. Must be able to hire and train a production crew, set up production and quality control procedures, supervise and install all equipment, and be completely responsible for all phases of the production of acoustic and electric guitars. Knowledge of electrical systems is quite secondary. (Jan.)

E-410—Openings for 2 engineers or wood tech. graduates with 2–4 yrs. plywood experience. Have additional openings for recent graduates with little or no experience. Employment is in the expanding lumber and plywood development dept. of a large diversified manufacturer. Opportunities exist for advancement within the dept. or elsewhere in the company. (Jan.)

E-411 Wood Technologist, preferably with background in composition board field, wanted for process and quality control work in large Westcoast particle board mill. Good opportunity for capable young man. (Jan.)

Employment Wanted

626—Management position in production, engineering, quality control or technical service in woodworking industry wanted by University graduate in B.S. with Forestry and 10 years experience in industry. Experience in production supervision in furniture and dimension business; wood technologist. Product engineering and quality control in other woodworking industries. Desire position with progressive and technically minded company. Age 34, married, 2 children. (Jan.)

627—Wood Finishing and contract woodwork procurement specialist. Bachelor degree in wood technology. Solid research and development background. Ten years experience with nationally known producers of quality products. Developed complete specifications, followed through on inspection and quality control, production trouble shooting, etc. Designed and installed fully conveyorized layouts. Thoroughly familiar with all phases—yard through finished products. (Jan.)

628—Can operate and maintain machinery. Agricultural background. have completed courses in Heavy Duty Equipment Machinery and in Conservation. Age 41. (Feb.)

629—Graduate with B. S. in Forest Products from Oregon State College desires position in sawmill, plywood production control or research and development. Four years experience in Douglas Fir plywood production engineering. Last 5½ years doing research on all phases of lumber manufacturing improvement. Prefer West Coast or Western Pine area. Married, age 36, two children. (Feb.)

630—Wood Technologist with 5 years experience in board products seeks position in reseach center, domestic or overseas. Experienced in product development, statistical design and analysis, translations. 5 foreign languages, published articles, honor societies. $10,000. Prefers urban North. (Feb.)

631—Position desired in particle board production or quality control. Four years experience in particle board operation as control technologist and production manager. B. S. Univ. of Minnesota in Forest Products. Prefer North or West. Married, age 27. (Feb.)

632—Want responsible position in forestry. Recent experience has been administrator, policy consultant, and research director. Have also been active in field work, research, mechanical development and teaching. B.S., M.S. Forestry. Married, age 45, three children. (Feb.)

633—Chemist, wood technologist desires responsible position with progressive company manufacturing or contemplating manufacture of wood adhesives. Extensive experience in all types and in all phases including development, sales, and service. Nationally recognized authority on animal and polyvinyl adhesives. (Feb.)

CROSS SECTION

. . . Voice of Membership

Thank You!

Editor: On behalf of the Midwest Section, I would like to thank you for the complete coverage you gave our Fall Meeting in the December Journal.

K. E. Kimball, Secretary
Midwest Section

Requests to Editor

FPRS activities are news to many other associations and societies. Many trade journals also request the right to reprint Journal Material. Here's a quick look at some recent requests. *Editor:*

. . . interested in information on pine veneer . . .
H. E. Bovay, Jr., Consulting Engineers
Houston, Texas

. . . obliged if you send us a copy of the technical note on show-through of particle board coares.
Howard Smith Paper Mills Limited
Montreal, Canada

. . . appreciate information on wood finishes . . .
Guild Guitars, Inc.
Hoboken, New Jersey

. . . particularly interested in "Wood Carbonization in Small Kilns."
Friendly Wood Corporation
Bethel, Conn.

. . . appreciate a copy of Dr. Monie Hudson's paper on "Quality Control by Toluene Extraction in Procurement of Cresoted Marine Piling," which appeared in July Journal.
Pittsburgh Testing Laboratory
Pittsburgh, Pa.

. . . transport of pulpwood chips in pipelines . . .
American Pulpwood Association
Sylacauga, Alabama

. . . wood flour in polyurethane foam . . .
Synvar Corporation
Wilmington, Delaware

. . . European particle board standards . . .
Willamette Valley Lumber Co.
Dallas, Oregon

. . . Wood's Future in Packaging . . .
Bathurst Power & Paper Co., Ltd.
St. Laurent, Quebec

. . . fundamentals of wood drying . . .
State Institute for Technical Research
Helsinki, Finland

. . . published data on wood cutting research . . .
Pioneer Saws Ltd.
Peterborough, Canada

. . . fundamentals of wood drying . . .
Arthur D. Little, Inc.
Cambridge, Mass

. . . layout of excelsior mills . . .
American Excelsior Corporation
Oshkosh, Wis.

. . . charcoal processing . . .
Vermont Bureau of Industrial Research
Northfield, Vermont

. . . dielectric heating . . .
Borden Chemical Co.
Seattle, Wash.

. . . information on flapreg . . .
Line Material Industries
Milwaukee, Wis.

Requests From Trade Press

. . . would like to publish . . .

Adhesives Age
New York, N. Y.

American Society for Abrasives
Reading, Pa.

Australian Timber Journal
Sydney, Australia

Canadian Woodworker
Don Mills, Ontario, Can.

Carpenter and Builder Journal
Madison, Wis.

Crow's Lumber Digest
Portland, Ore.

Gardner Laboratory, Inc.
Bethesda, Md.

Hitchcock's Wood Working Digest
Wheaton, Ill.

Industrial Woodworking
Cos Cob, Conn.

National Fire Protection Assoc.
Boston, Mass.

Packaging Progress
Montreal, Can.

Paper Mill News
New York, N.Y.

Plywood
Indianapolis, Ind.

Quebec Lumber Manufacturers Assoc.
Quebec, Can.

Radiata Pine Assn. of Australia
Adelaide, South Aust.

Sikorsky Aircraft Corp.
Stratford, Conn.

The Timberman
Chicago, Ill.

Timber of Canada
Ontario, Can.

Wood & Wood Products
Chicago, Ill.

CURVED PLYWOOD?
Made to specification
High-Frequency bonding on low cost forms
Tell us your problem — we'll solve it to your specifications. We manufacture unusual plywood shapes for applications ranging from church pews to water skis . . . table legs to torpedo cradles. Our high-frequency presses mass-produce curved parts fast and at lower cost than other methods, and with greater stability. We have over 200 stock dies available for stock shapes. Write, wire or phone RI 2-2474 for quotations and complete engineering service.
PLY-CURVES INC.
1615 Monroe Avenue, N.W., Grand Rapids 5, Michigan

See Reader Service Form, page 48.

FPRS FOREST PRODUCTS JOURNAL VOL. XI, NO. 1 JANUARY, 1961

Acrylic Emulsion Paints[1]

FOR EXTERIOR WOOD SURFACES

CALIFORNIA HOME was painted with acrylic emulsion paint in August 1953. Paint was applied over old oil paint on redwood siding. Present condition: extremely good color retention and adhesion; very clean and white, mild chalking, no blistering or peeling.

7 SEVEN YEARS EXPOSURE TESTED

GEROULD ALLYN
Rohm & Haas Co., Philadelphia, Pa.

THE RAPID INCREASE in the use of emulsion or latex type paints has been one of the most interesting developments in the history of the paint industry. Introduced little more than a decade ago, they now comprise at least 10 percent of all paint sold in the United States.

Industry estimates and census figures on sales and production of these water-thinned paints vary considerably, but according to recent estimates[2] approximately 69.4 million gallons of latex paints were sold in 1959. Sales were estimated to be divided as follows:

Emulsion Used	Millions of Gallons	Percent of Total
Butadiene styrene	38.0	55
Polyvinyl acetate	20.3	29
Acrylic	11.1	16

Industry estimates indicate that sales of latex paints in 1960 probably increased approximately 10 percent over the 1959 figure. Most of this increase probably occurred in the acrylic and polyvinyl acetate types.

A good deal of this expansion has been at the expense of paints containing linseed oil. While sales of the latex paints do not account for all of the difference, sales of linseed oil declined to around 400,000,000 pounds in 1959 in contrast to approximately 800,000,000 pounds a decade ago.

There are few reliable statistics available on the production of the various types of latex paints. However, the Census of Manufactures for 1958 and 1954 give some bench marks in this field which are the best available. Values given for production of latex and other water-thinned paints are shown below.

Types of Paint	1958 (1000's of Gallons)	1954 (1000's of Gallons)
Other exterior water-thinned paints	4,272	1,664
Interior latex base paints		
Acrylic	4,168	—
Butadiene styrene	33,152	29,406
Vinyl and others	12,123	3,139
Resin and other base paints	1,181	1,814
	54,896	36,023

Total production of water-thinned paints in the United States increased slightly more than 50 percent from 1954 to 1958. Paints based on butadiene styrene latices dominated the market in 1954 and held over 60 percent of the market in 1958. Production of paints based on polyvinyl acetate emulsions increased almost four-fold in the same interval. Figures for acrylic emulsion paints were not published separately in 1954, but estimates by Rohm and Haas Company indicate a five-fold rate of growth.

This increase in production and sales of latex and emulsion paints has been marked by advances into new fields of application. The original butadiene

In the past few years, acrylic emulsion paints have gained widespread use for application to wood surfaces. They have excellent blister resistance, long-term durability, and they are easy to apply. One caution: an oil-base primer is needed on bare wood or heavily chalked surfaces to prevent peeling and cracking.

The Author: Mr. Allyn's industrial experience includes 23 years of research, production, and technical development work on synthetic resins and white pigments. He has been with Rohm & Hass for 14 years, concentrating primarily on technical development of protective coating resins and emulsions.

[1] Some of this information was originally presented at FPRS 13th Annual Meeting, June 30, 1959. Since then the material has been revised to include new data; revised manuscript received Dec. 23, 1960.

[2] American Paint Journal, Aug. 15, 1960

styrene latex paints, introduced in 1947 and 1948, were recommended for use on interior surfaces such as plaster, cinderblock, cement and wallboard. Acrylic emulsion paints, introduced early in 1953, were first suggested for similar interior surfaces. Some paint manufacturers and users, particularly in California and in the South, immediately started test work on exterior coatings for stucco, masonry and cinderblock. Preliminary results were so encouraging that a number of exterior acrylic emulsion coatings for masonry soon appeared on the market.

Early work with exterior masonry paints based on emulsions of polyvinyl acetate homopolymers was also underway at the same time, particularly in the Los Angeles area. These early homopolymers gave good results in the dry climate of the Southwest, but they were not so satisfactory in wetter or colder climates as the polyvinyl acetate copolymers developed later. Use of both polyvinyl acetate and acrylic coatings for exterior masonry expanded rapidly, and this development is continuing. Paints made with both polymers also invaded the interior masonry, plaster and wallboard fields held by butadiene styrene.

In late 1958 and early 1959, acrylic emulsion paints began to receive widespread acceptance for a different surface, exterior wood. At the present time, most of the major paint producers have an emulsion-paint system for exterior wood surfaces. The majority of these paints are made with acrylic emulsions either of the 100 percent acrylic type or with some modifica- polyvinyl acetate copolymers in their exterior emulsion-paint systems for wood. Paints based on butadiene styrene latices have relatively poor adhesion to bare wood and have not received widespread acceptance for this application.

Consumer Acceptance

It is expected that due to consumer demand for these new coatings for wood, sales and production of latex paints will continue to increase rapidly in the next few years.

There are a number of reasons why emulsion-paint systems for wood, and acrylic emulsion paints in particular, have become popular so rapidly. There are also some negative factors regarding the acceptance of these new coatings. A summary of these points follows:

Easy Application: Anyone who has applied one of the new emulsion paints for wood surfaces will readily agree that easy brushing is one of their biggest assets. Wide brushes can be used and the slight brush drag permits the painter to work rapidly and accurately. However, this ease of application can also be a disadvantage since the painter may not apply enough paint to give good hiding and good durability. Paint manufacturers give recommended spreading rates of around 450 square feet per gallon, and users must adhere to these rates for optimum durability and hiding power.

Excellent Appearance: Emulsion paints give excellent appearance both initially and on aging, even when applied by an unskilled painter. They can be readily touched-up if areas are inadvertently omitted. The paints have excellent whiteness and retain this whiteness on aging. Tinted or deep-colored paints show excellent color retention, considerably better than oil-based paints.

Quick Dry: If two coats are to be applied, the second coat can be put on 30 minutes to 1 hour after the first coat. This saves considerable time because one scaffold setting will take care of both coats. Fast drying means that sudden showers will not harm a freshly painted surface. Quick drying also reduces the problem of bug and dirt collection characteristic of slow drying paints.

Excellent resistance to blistering: Properly formulated emulsion paint systems have excellent resistance to blistering on wood surfaces. With the trend to small, tightly sealed houses, and with the types of formulations used in recent years, blistering has become a serious problem with many oil-paint systems. Properly formulated emulsion-paint films have relatively low rates of swelling when immersed in water. Work by Dr. F. L. Browne of the U. S. Forest Products Laboratory[3] has demonstrated that paint systems with relatively low swelling rates have the best chance of resisting blistering when used on wood surface. It is necessary to remove old non-blister resistant paints and use a blister-resistant primer in order to get a highly blister-resistant system.

Outstanding Durability: Acrylic emulsion paints give outstanding outdoor durability because the acrylic emulsion base has excellent resistance to degradation by oxygen, heat, and ultraviolet light. While there is some reduction in elongation and an increase in tensile strength on exposure, repeated studies have shown that acrylic systems resist degradation extremely well. For example, clear films of

[3] Browne, F. L. Swelling of paint films in water. VII. Latex vehicles. For. Prod. Jour. Vol. 6, No. 6, pp. 235-240.

ACRYLIC EMULSION PAINT retains excellent adhesion and appearance on cedar shingles and wood trim after 4 years of exposure on home in Philadelphia. One coat was brushed on. Colors were dark brown on shingles and white on trim. Some peeling was noted at last inspection where paint was applied on trim over glossy surface under eaves.

acrylic emulsion, exposed for 100 hours in a Fadeometer, show an elongation of 44 percent initially and 429 percent after exposure. Tensile strength increased from 2126 psi to 2683 psi. Other types of clear films show much greater reduction in elongation and a much greater change in tensile strength than this. Some increase in strength, and some degrade severely. After 3000 hours of exposure in a Fadeometer, the acrylic films were still clear, tough, and flexible while most other types of films yellowed, cracked, and checked. These durability properties have been fully confirmed by 7 years of outdoor exposures on test panels and commercial buildings.

Resistance to Cracking and Checking: Both paint films and wood, when subjected to changes in temperature and moisture content, undergo changes in their dimensions. Changes in dimensions of acrylic paint films come somewhat closer to those of wood than many other types of films, particularly films of linseed oil containing zinc oxide. However, emulsion—paint films have relatively high rates of moisture vapor transmission. Consequently, it is necessary to use an oil-based primer on bare wood surfaces to prevent early grain cracking of some types of wood from rapid changes in moisture level.

Adhesion: There are considerable differences in adhesion to previously painted surfaces with the different types of emulsions used. When the old surface is sound and relatively clean, acrylic emulsion paints have an advantage in adhesion compared to the other emulsion types.

Application to Damp Surfaces: Emulsion paints can be applied to surfaces wet from rainfall or heavy dew. This characteristic means that no time

ONE OF THE OLDEST commercial applications of acrylic emulsion paint in the country. Redwood siding had previously been oil-painted. Two coats of 30 percent pigment volume acrylic emulsion were applied in August 1953. Front of Pasadena, California home was retouched in August 1960 because of stains caused by water sprinklers.

CEDAR SHAKES on home in Philadelphia were given one coat of barn red acrylic house paint September 1953. Paint was applied over 4-year old brown stain with no surface preparation. Present condition; excellent, with no signs of chalking or blistering.

need be lost waiting for surfaces to dry out. In fact, adhesion is often improved if surfaces are hosed down and allowed to drain before painting.

Easy Clean-up: It is easy to clean brushes or rollers when emulsion paints are used. These tools can be simply rinsed out in soapy water.

Reduced Fire Hazard: Flammable solvents are not needed with emulsion systems either for application or brush clean-up. There is no hazard from oily rags left after the job is done.

Advantages of Oil Paints

Despite this very impressive list of advantages for the latex paints, they have some disadvantages in comparison with oil systems. These may be summarized as follows:

1) Emulsion paints have lower solids than oil paints. This results in a thinner film and less hiding power per coat of paint.

2) A separate specialized oil-based primer is required on bare wood surfaces to prevent color bleed, and premature grain cracking, cupping or warping of the wood. This primer is also needed on chalky surfaces for adhesion and on bare iron to prevent rust stains.

3) The oil paints have more brush drag so that they can not be brushed out to give excessively thin coats with limited durability.

4) One coat of oil paint is often sufficient for repainting; whereas, manufacturers specify a special primer and at least one topcoat for the emulsion systems.

5) Oil paints have had a long history of exposure, and more predictable results can be obtained.

Application Requirements

Most of the requirements for good painting practice with oil paints also prevail for emulsion paint systems. It is necessary to brush, roll, or spray one or more coats of suitable thickness at the recommended spreading rate. Surfaces should be free from heavy chalk, dirt or mildew. Old peeling, cracked, or blistered paint films must be removed or early failure will result with all types of exterior paints, whether oil or emulsion base.

Where emulsion paints are to be applied over old paint in protected areas, it is essential to wash down the surface of the oil paint. There are some indications that clear water is at least as effective and in many cases better than the use of water with detergents. Soaps should be avoided since they leave a water-repellent residue.

It is helpful to reduce the gloss of the old paint in protected areas either through sanding, rubbing with steel wool, or washing with one of the commercial gloss removers. These treatments also remove dirt that tends to collect in sheltered areas.

In hot, dry weather, it is advisable to dampen the surfaces before painting. This helps to cool the surface and adds a small amount of water which prevents excessively rapid drying of the paint.

Emulsion paints should not be applied at low temperatures. The particular temperature depends on the formulation of the paint involved, but a safe guide generally is a minimum temperature of 50°F.

Painting on Bare Wood

Observations on test panels and houses indicate that emulsion paints will do their best job when they are applied over a primer on bare wood or burned-off wood. A blister-resistant oil or alkyd primer is needed to reduce the moisture transmission in and out of the wood surface. Unless this is done, grain raising, warping, and cupping, or bleed-through of wood colors will occur.

There have been a number of attempts to produce complete water-thinned systems for wood comprising a water-based primer and a water-based topcoat. These primers have met with moderate success, but they have some limitations. One type of water-thinned primer that has been suggested is the emulsified oil or alkyd. This type of primer can be reduced with water. It has some of the advantages of water systems but drying time before recoating is slow, often 24 hours or longer. Also, there have been problems with color-bleed and with stability on storage and during application. Another type of primer suggested particularly for redwood and cedar consists of an acrylic emulsion base with basic lead silicate at low pigmet volume content to inhibit color-bleed. Often a primer of this type shows stains from the wood. The color seems to be tied up quite effectively in the primer, however, and the stain is not transmitted to the emulsion topcoat. Such a primer provides somewhat better resistance to grain cracking than a conventional emulsion topcoat used as a primer, but on woods in which cracking is a problem, such as southern yellow pine, an oil-based primer will give better results.

Table 1.—FORMULATIONS OF ACRYLIC PAINT USED IN THE 1953 EXPOSURE SERIES*

Material (Pounds per 100 gallons)	Formulation Numbers 6	7	10	13	14	15	17	18	21	22	23
Titanium dioxide (Free-chalking anatase)	-----	-----	100.0	-----	94.3	97.3	-----	112.5	-----	-----	87.5
Titanium dioxide (Non-chalking rutile)	200.0	200.0	100.0	165.0	94.3	97.3	220.0	112.5	210.0	182.0	87.5
Talc	93.2	189.5	185.5	197.0	-----	-----	-----	251.5	-----	-----	-----
Water-ground mica	-----	-----	-----	-----	174.0	-----	-----	-----	307.0	-----	-----
Diatomaceous silica	-----	-----	-----	-----	-----	162.0	-----	-----	-----	235.0	-----
Calcium carbonate	-----	-----	-----	-----	-----	-----	293.5	-----	-----	-----	359.0
Rhoplex AC-33 (46%)	761.0	631.9	634.2	559.0	600.0	623.0	574.0	513.0	377.0	345.0	415.0
Pigment volume content (%)	20	30	30	30	30	30	40	40	50	50	50
Total solids (%)	57.7	60.0	60.0	57.4	56.2	58.8	63.9	60.4	60.3	52.0	56.7

*All of these paints contained dispersant, anti-foamer, and preservative in addition to the items shown.

Oil primers without zinc oxide show minimum swelling and give good blister resistance. One satisfactory primer for use under emulsion paints is described in Federal Specification TT-P-25A. A primer of this sort should be allowed to dry for 2 or 3 days before the topcoats are applied. If two coats of emulsion paint are desired over the primer, the second coat can be applied within an hour after the first.

Interestingly enough, the first outdoor exposure tests on acrylic emulsion paints were conducted on yellow pine surfaces without oil priming. These tests were started in 1953, and some of these panels are still in reasonably good shape on the test fences after 7 years of exposure. Details on these paints are given later. As indicated above, however, in commercial applications an oil primer should always be used for consistently good results.

Previously Painted Wood

Previously painted wood surfaces should be examined carefully before repainting. If the existing coating is cracking, flaking, peeling, or blistering, it is essential to burn off the old paint and prime with an oil primer before applying the topcoats.

Chalking of old paints must also be considered. Results to date indicate that if moderate chalking is present, the surface to be coated can be washed down with a hose before the topcoats are applied. If the surface is chalking heavily, however, the chalk should be washed off and the surface allowed to dry thoroughly. An old-base prime coat should be applied, allowed to dry, and then one or two topcoats of emulsion paint should be applied.

Emulsion Paints for Wood

A great many different types of formulations and formulation variables have been proposed for acrylic emulsion paints for wood surfaces. It is beyond the scope of this article to cover these variables in detail. Those interested can find full details in a series of progress reports on acrylic exterior paints.[4] These reports, issued annually for the last 7 years, give formulation information, application procedures and exposure results on many different acrylic paints on wood and masonry surfaces.

The 7-year test program by Rohm and Haas Company has served to define rather clearly the formulation limits that give good results on exterior wood surfaces.

Pigment Content: The pigment content of an emulsion paint affects its durability properties in a number of ways. In general, paints made with acrylic emulsion at pigment contents in the range of 30 to 35 percent by volume, will show better durability properties on long-term exposure than similar paints with higher pigment content. The rate of chalking will be lower, the resistance to staining will be higher and the adhesion and toughness properties will be better. Dirt collection will be high at pigment concentrations below 28 percent. Colored paint formulations should also be in the 30 to 35 percent range of pigment content for best tint retention.

The amount and types of titanium dioxide used in a formulation are very important factors affecting the performance, appearance and cost of white exterior coatings made with the acrylic emulsions. In addition to its major role of providing hiding characteristics, the titanium dioxide content controls to a considerable degree the rate of chalking, dire retention, and erosion.

[4] Annual Progress Report No. 7 (1960): Rhoplex AC-33 & AC-55, 100 percent acrylic emulsions for exterior paints. Rohm & Haas Company, Philadelphia 5, Pa.

Formulators differ on the ratio of non-chalking titanium dioxide to chalking type which should be used in a formulation for best appearance and performance. Our test work indicates that for white paints to be used in the northern United States the titanium pigment should consist of approximately 85 percent non-chalking rutile, the balance being semi-chalking or free-chalking anatase. For paints exposed under tropical conditions, most formulators prefer that non-chalking rutile titanium dioxide comprise 90 to 100 percent of the titanium content.

In white formulations containing no free-chalking titanium dioxide, chalking may not start for 2 or 3 years after exposure. However, such formulations eventually chalk at a reasonable rate.

The chalk on acrylic emulsion paint films is tightly bound to the surface. Such paints give excellent resistance to chalk rundown on bare brick or masonry surfaces which may be below them on the side of a building.

The amount of titanium dioxide in the formulation also has an effect on the chalking rate. Paints that contain 1-¾ pounds titanium dioxide per gallon chalk less than paints that contain greater amounts, such as 2 to 2-½ pounds per gallon, of the same pigment.

For tinted or colored paints, it is essential that straight rutile non-chalking titanium dioxide be used. The total amount of titanium dioxide in tinted paints should be kept to a minimum to reduce chalking tendencies to the lowest possible value.

Table 2.—RATINGS ON 1953 EXPOSURE SERIES AFTER SEVEN YEARS*

Paint Number	Dirt Retention	Chalking (18 Months)	Chalking (33 Months)	Chalking (7 Years)	Grain Cracking	Flaking	Erosion	Mildew
6	5.0	9.5	9.0	8.3	6.0	9.7	10.0	8.0
7	7.0	10.0	9.3	6.3	6.0	9.3	10.0	4.7
10	8.5	9.3	2.0	4.5	7.0	10.0	7.5	9.0
13	6.0	10.0	9.5	6.5	5.0	9.5	10.0	5.0
14	9.0	7.0	4.5	3.2	7.0	8.7	9.0	8.0
15	9.0	9.0	5.5	3.3	4.5	8.5	9.0	9.3
17	5.5	10.0	9.7	9.0	5.5	9.2	10.0	4.5
18	9.0	8.5	1.0	2.0	4.5	7.0	7.5	8.0
21	6.0	9.5	9.0	7.0	4.0	5.0	10.0	9.3
22	7.0	9.5	9.3	5.0	5.5	8.0	10.0	8.0
23	8.0	9.0	6.0	5.0	6.5	9.5	9.0	7.0

*Two coats of each paint were applied to southern yellow pine. Specimens were subjected to south vertical exposure in the Pennsylvania area. A rating of 10.0 indicates no failure; a rating of 0.0 indicates complete failure.

Thickeners: The use of large quantities of thickeners to increase paint viscosity and to reduce costs is definitely detrmimental to outdoor durability. Thickeners are soluble in water and tend to swell when the paint film is wet, thus reducing film durability. Since the solids content in highly thickened paints is reduced below normal, durability is further reduced.

Preservatives: Emulsion paint films themselves are not readily attacked by mildew and mold. The dirt that collects on a painted surface can support mildew growth however, so an effective preservative must be used by the paint manufacturer. This problem is further aggravated on wood surfaces because the wood can furnish solubles that supply the basis for mold growth. It is also necessary to use a preservative in the oil-based primer. Since adequate preservatives are expensive, they are occasionally skimped on in "cut rate" paints with a corresponding sacrifice in durability and appearance.

Results of Exterior Tests

Many exterior formulations and results of exposure tests have been given in the series of progress reports referred to earlier. One of the earliest series of paints reported in these reports was put on exposure in 1953. Many of these paints are still on exposure. An outline of the more interesting formulations in this relatively old test series of paints is given in Table 1. Exposures were south vertical in the Pennsylvania area, and the wood was yellow pine. Two coats of acrylic paint were applied without an oil primer. Table 2 gives data on the condition of these paints after 7 years of outdoor exposure.

Some comments on these results may be helpful. Paints such as Nos. 6, 7, and 17, which were made with straight non-chalking rutile titanium dioxide, show the most dirt collection. Low pigment volume concentration also increased the amount of dirt collected. Chalk rates for these straight rutile paints are lower than for the paints containing free-chalking anatase titanium dioxide. The paints with anatase dioxide all contained a 1:1 ratio of anatase to rutile grade. This ratio is now known to be much too high for optimum results and gives fast rates of chalking. Despite this high ratio of free-chalking pigment, however, ratings for erosion are moderate even after 7 years of expsoure.

Grain cracking of the yellow pine panels occurred in all of these exposures. It should be pointed out that these panels had two coats of emulsion paint without an oil primer. Our test work shows that an oil primer should be used for optimum results on all bare wood surfaces. Paints with lower pigment volumes contents in general gave less grain cracking, but the differences were not large.

Flaking occurred to some extent on all paints except No. 10. In general, paints with low pigment gave least flaking, although paint No. 23 with 50 percent pigment volume had a good rating.

Erosion is now starting to take place on several of the paints that showed no erosion after 6 years of exposure. As shown in many tests, however, the rate of erosion on acrylic emulsion systems is low compared to oil paints. Consequently, even though the films are thinner than films of oil paints, long-term durability is obtained.

All of the paints are showing some mildew attack after 7 years of exposure. Most of the mercury preservative has undoubtedly been leached out of these films. The mildew ratings are approximately in inverse ratio to the chalking ratings, which indicates that chalking pigment removes mildew as it washed away. Another factor that affects mildew ratings is the amount of grain cracking on the panel. Cracks permit solubles from the wood to be deposited on the surface, thus encouraging mildew growth.

TAPPI REPORT: Pulpwood Properties

The TAPPI Forest Biology Committee Report, (Progress Report No. 1, Project 697, Tappi 43, no. 9 [Sept., 1960] describes the ways in which industrially significant properties of pulpwood are reflected in pulp and paper processing and in the properties of paper. Entitled "Pulpwood Properties–Response of Processing and of Paper Quality to Their Variation," this report summarizes current information on the effects of wood density, proportion of springwood and summerwood, growth rate, chemical composition of wood, fiber length (average and distribution), fiber width, fiber wall thickness, fibrillar angle, fiber strength as it exists in the wood, fiber-to-fiber bonding strength, knotwood, reactionwood, and proportion of nonfiber wood cells.

Also included are brief discussions of correlations between wood properties, including "core wood"—"outer wood" contrasts, and with respect to several wood properties, of the degree of improvement which might be considered economically important.

The need for many further studies of wood properties, wood property-pulp property relationships and fundamental factors and behaviors in papermaking is underlined. Finally, the report emphasizes that the forest biologist and forest manager who are seeking to improve the quality of pulpwood are not yet in a position to apply more than a few of the wood property recommendations which can today be offered by the pulp and paper scientist. This conclusion is reached in view of the inadequacy of information about the heritability of wood properties and regarding the kind and degree of influence upon wood properties which can be achieved through practical control of environmental factors. The general prospect, however, of obtaining more of, and for being in a position to apply, the requisite fundamental understanding is considered promising.

The report was prepared in recognition of the growing need for technical interchange between foresters and papermakers, and is the joint effort of some 25 collaborators representing pulping and papermaking, forest biology, and woodlands operations and research. It was prepared by the Forest Biology Committee of the Technical Association of the Pulp and Paper Industry as a project of its Subcommittee on Tests and Quality Objectives. FPRS members contributing to this report are J. R. Salvesen, R. J. Seidl, R. F. Sultze, Jr., E. F. Thode, R. M. Echols, H. L. Mitchell, M. Y. Pillow, F. F. Wangaard, P. T. Lannan, Jr., L. Besley, I. H. Isenberg, and J. E. Stone.

Reprints may be secured by writing B. K. Mayer, Secretary, TAPPI Forest Biology Subcommittee No. 2, on Tests & Quality Objectives. c/o Oxford Paper Company, Rumford, Maine.

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Seasoning Green-Wood

A NUMBER OF CRAFT INDUSTRIES and a host of wood hobbyists are either using or experimenting with polyethylene glycol-1000 to season green-wood turnings and carvings. In this application, the idea is simply to get enough of the chemical into the green wood to prevent the splitting and checking that so frequently develop in green carvings or thick blocks of untreated wood dried by conventional methods. Little or no data have been published on the minimum treatment needed to achieve this limited objective, so guidelines for such chemical seasoning have been largely lacking.

In the experiments here reported, one dozen each of several standard green-wood carvings produced by the Crane Creek Company (see illustrations) were soaked in a 30 percent (by weight) solution of polyethylene glycol-1000 for various times and at different temperatures. Treating was done in plywood-lined soaking vats that were electrically heated and thermostatically controlled. The solution in the vats was circulated periodically to maintain uniform temperature conditions. Immediately following the soaking, samples were cut off two carvings from each treatment, and analyses were made to determine the amount of polyethylene glycol in the outer 1/8 inch. All carvings were shaped on a duplicating lathe from blocks cut from a single, fresh-sawn walnut flitch.

PAPERWEIGHT, PENCIL HOLDER, AND GAVELS made at the Forest Products Laboratory from wild-grain hard-to-season woods that were chemically treated and then dried to flawless perfection.

Treating Schedules

The following tabulation shows the number of days the carvings were soaked in a 30 percent solution of polyethylene glycol, the temperature of the solution, and the amount of chemical—expressed as a percentage of the dry weight of the wood—found in the outer 1/8 inch of the carvings.

Time Soaked (Days)	Temperature (°F.)	Glycol (%)
4	140	10.1
8	130	6.7
14	130	8.6
14	65	6.4
21	65	11.8

Drying Conditions

Half of the carvings from each treatment were subjected to rather drastic drying conditions in a conditioning chamber maintained at constant 30 percent relative humidity and 80° F. The remaining carvings from each treatment were simply dried on shelves in a heated shop (average temperature about 65° F.) with no humidity control. In addition, 12 untreated (control) green-wood carvings were dried under each condition.

Results

All of the chemical treatments listed above resulted in 100 percent of the carvings being completely free of splits, surface checks, warp, and other seasoning degrade for both drying conditions. When the untreated controls were subjected to the same drying conditions, 70 percent of the carvings were declared culls or rejects after the drastic drying (80° F. and 30% R.H.), and 25 percent were culls after the moderate (65° F.) drying condition.

No noticeable difference was observed between carvings soaked for different times at various temperatures; all were absolutely free of splits, surface checks, and warp. It appears, therefore, that even lighter treatments would afford adequate protection for walnut green-wood carvings. Possibly very short soaks of from 12 to 24 hours at temperatures of 140° F. to 180° F. would do the job, especially for carvings that are to be dried under moderate conditions.

Maple and Cherry

Although these studies were primarily concerned with walnut, a few black cherry and hard maple carvings were included in treatment No. 2. (8 days at 130° F.). The cherry carvings behaved exactly the same as walnut during drying, although they had about 10 percent less polyethylene glycol in the outer 1/8 inch of wood. The maple carvings, however, behaved quite differently during drying, even though they absorbed slightly more chemical than similarly treated wal-

The authors: Harold Mitchell is Chief of the Forest Products Laboratory's Division of Timber Growth and Utilization Relations; E. S. Iversen is a forester at The Crane Creek Gun Stock Company.

[1] A contributed paper received December, 1960.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

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GREEN-WOOD CARVINGS the size and shape of this Irish setter are exceedingly difficult to dry defect-free without treatment with polyethylene glycol, which is 100 percent effective in preventing seasoning degrade.

ORIGINAL CARVINGS (l.) AND REPLICAS (r.) that were rough-shaped from green walnut, treated with polyethylene glycol-1000, dried defect-free under drastic conditions, and are now ready for final shaping and finishing.

Carvings With Polyethylene Glycol-1000[1]

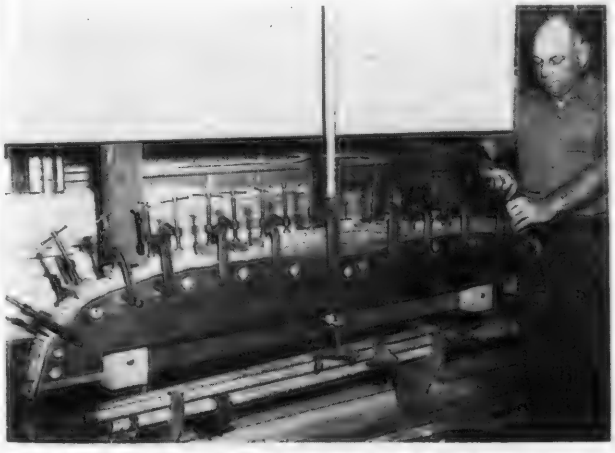
nut. Serious splits developed in most of the maple carvings, including those exposed to moderate drying conditions. Maple carvings evidently require heavier treatment to afford adequate protection during seasoning. This is in line with experience gained working with chemically stabilized walnut and bird's-eye maple rifle stocks.

Dimensional Stability

In conclusion, it should be emphasized that relatively light treatments, such as used in these studies, do not result in a high level of dimensional stability in the finished product. If the objective is to treat wood so that it is permanently restrained from shrinking, swelling, and warping, then heavy treatments that result in polyethylene glycol retentions of from 25 to 30 percent are necessary.

Good examples of special products in which heavy chemical treatments are being used successfully to achieve the high level of dimensional stability essential to proper performance include stocks for precision bolt action rifles[3] and the maple core laminations in composite recurved bows. Even small dimensional changes in critical areas of the stock can throw a rifle barrel ever so slightly out of alignment and thus impair its accuracy. In composite recurved bows, appreciable shrinking or swelling of the wooden (usually maple) core laminations, between the glass faces, frequently result in twisted tips that render the bow useless. According to bow manufacturers, this type of failure is common in areas of high humidity, particularly the Gulf States. Recent tests indicate that such difficulties can be largely prevented by using maple core laminations that have been heavily treated with polyethylene glycol-1000.

[3] "New Chemical Treatment Curbs Shrink and Swell of Walnut Gunstocks," by Harold L. Mitchell and Harold E. Wahlgren. 1959. Forest Products Journal IX (12):437-441.



HAROLD L. MITCHELL in home workshop laminating composite recurved bow on gluing form. Use of chemically stabilized maple veneer for core laminations, between glass faces, prevents bow tips from twisting in hot, humid weather.

"TILLERING" NEARLY FINISHED RECURVED BOW, made of chemically stabilized core laminations between glass faces, to check limbs for action, uniformity of bend, and freedom from twist. Bows are good examples of products requiring heavy chemical treatment.

Linear Programming in Log Production[1,2]

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Here is a mathematical analysis to find out how to make the most money out of a tree. There's no need to take a computer to the woods, but if the basic information is gathered accurately, here's what linear programming will do for a logger:

- **Give him organized facts about logging problems.**
- **Analyze alternate solutions for these problems.**
- **Select the best course of action for him to follow.**
- **Plan a specific cutting program for maximum profit.**
- **Re-evaluate the program to fit prevailing markets.**

LOGGING CONTRACTORS AND OTHERS, engaged in the lumber industry are constantly called upon to make decisions aimed at combining their resources in a manner that will yield a maximum profit. In making these decisions, they usually think in terms of improved manufacturing devices, more efficient use of labor, or more adequate transportation facilities. Another and equally important approach to increased profits, however, is through more economical utilization of trees subject to existing market restrictions. Although this segment of the total operation is often overlooked, it is possible that sawmill owners and logging contractors can improve the profitability of their operations by developing more efficient methods of tree utilization.

Good business in this industry starts in the woods when the trees are felled. After the tree is on the ground, the bucking crew begins to make some fundamental decisions that are as important as any that are made in the total process of manufacturing lumber. The crew members who use the measuring stick and axe not only determine the length of the lumber produced by the sawmill, they also have a very definite effect on the net returns of both the logging contractor and the sawmill operator. They must choose the method of tree "break-down" that will yield the highest profit to the enterprise from a wide variety of alternatives. At the same time, the logging crew must produce log lengths that will satisfy the restrictions placed on the mill operator by the concentration yard buyer.

Many penalties result from poor logmaking. Two of the most important ones are: (1) the loss of volume from inefficient utilization, and (2) the overproduction of lengths that have low market demand or price.

While the operators are generally aware that profits can be increased by a well-organized program of log production, there has been no demonstration of a specific technique that would be sufficient for them to use as a guide in obtaining maximum returns under existing market restrictions. Thus, the logging operator has had to rely on informal or intuitive methods in his attempt to satisfy market limitations and simultaneously increase his income.

It is proposed here to show that linear programming is a mathematical model for these decisions in the logging industry. The procedure may involve either maximization or minimization of some function, subject to certain constraints. This technique was first developed by economists who applied it to problems of the national economy. It is now being applied on an industrial basis to problems involving transportation scheduling, manufacturing activities, and marketing methods.

Most commonly, linear programming has been used to solve problems in which certain limited resources are being converted into salable commodities subject to stated restrictions. Various ways for manufacturing these resources into commodities are available. The problem is to choose a particular activity or group of activities that will not only make the most efficient use of the resources, but will also meet the limitations imposed by the customer.

The problem of optimum log combinations for maximum profits in the logging industry lends itself to analysis by this technique for the following reasons:

1. There are a number of different alternatives that may be taken when converting trees into logs.
2. There is a different profit associated with each of these alternatives.
3. Market demand imposes certain limitations on the volume of each log length that can reasonably be utilized.
4. There is a goal established in terms of maximum profits.
5. A quantitative value can be assigned to each of the factors involved.

In the course of applying this type of mathematical analysis, specific examples are introduced. These examples are supported by data generated under normal operating conditions. It should be noted that optimality is achieved through the systematic selection of certain manufacturing activities rather than by remedial changes involving cost reduction or increased productivity.

Methods of Collecting Data

Construction of the Stand Table: Suppose a logging contractor has a stand of timber to be harvested. He has an estimate of the total volume and approximate number of trees based on a cruise made of the area. The cruise was developed by marking and scaling each tree and assigning the appropriate volume according to its d.b.h. (diameter, breast high) and merchantable height.

The data used in constructing the stand table shown in Table 1 are based on information taken from 645 trees cut on the Hill Forest, near Durham, North Carolina, from 1931 to 1955. These trees were felled specifically to obtain stem-analysis information or were cut in regular woods operations. The tree volumes used are taken from volume tables computed by Slocum and Miller (1953).

The Authors: George W. Smith is in charge of the Wood Products Extension Section at North Carolina State College. He has also served as an officer of FPRS Carolinas-Chesapeake Section. Cleon Harrell is an associate professor in the Department of Economics at NC State.

[1] Presented at FPRS Thirteenth National Meeting, June 28–July 3, 1959 in San Francisco; Approved for publication Dec. 6, 1960. The paper is a portion of a thesis submitted at North Carolina State College as part of the requirements for a Master's Degree in Wood Technology.

[2] A contribution from project No. HM-24 of the North Carolina Agricultural Experiment Station in cooperation with the Southeastern Forest Experiment Station, Asheville, North Carolina.

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Table 1.—MERCHANTABLE VOLUME IN BOARD FEET[1]

Diameter (d.b.h.) Inches	Number of trees	Volume per tree Board feet	Total volume per d.b.h. class Board feet
8	126	47	5,922
10	213	78	16,614
12	170	123	20,910
14	100	178	17,800
16	30	264	7,656
18	6	355	2,130
Total	645		71,032

[1]Based on the International ¼-inch rule to a 6-inch top inside bark; Form Class 0.80

Determination of Log Combinations: Following the construction of the stand table, it is necessary to determine how many possible log combinations may be cut from trees of each class. Some of these possible log combinations can be eliminated at the outset since other log cut-up alternatives are clearly more profitable. For instance, it is not desirable to convert a 16-inch tree into 8-foot logs as this increases labor consumption and produces a lower-priced product. Other similar unrealistic choices are omitted in listing the alternative ways of converting the trees into logs.

The following merchantability standards used in this investigation approximate those used by practicing foresters in the Southeast.

1. *Defects.* Due to the large assortment of defects encountered in timber throughout the country and the limited scope of this study, it was necessary to assume that the trees are normally straight and sound.

2. *Stumps.* All calculations were derived using a stump height of 0.75 feet. The entire merchantable length above this point was considered when selecting log combinations.

3. *Upper Limits.* Upper marchantability was considered ended at 6 inches d.i.b. (diameter inside bark at small end of log) for sawlogs and 4 inches d.i.b. for pulpwood sticks.

When selecting cutting systems for each tree class, the volume was established according to the d.i.b. of each log at the small end. These volumes were then summed to give the total tree volume (log scale) in board feet.

Collection of Time and Cost Data: The timber in which the time and cost data was collected was located in Wake County, North Carolina. It was a mixture of second-growth loblolly and shortleaf pine with a small amount of poplar and mixed hardwoods. The area was cut on a selective harvest system calling for the removal of about 7000 feet per acre, ranging from 6 to 20 inches in diameter. The topography was typical of the Piedmont area of North Carolina, ranging from low bottom land to gently rolling areas with flat areas intermediate. The cutting was observed in early summer when weather conditions were favorable.

The logging crew consisted of two men: one felled the tree and cut the logs with a chain saw; the other worked with an axe and a measuring stick. The second man also wedged where required or pried up on a log to relieve a pinch. In addition, he decided the length of logs to be cut and marked them for the chain saw operator. Limbing was also an important part of his work, although the chain saw was used occasionally to remove limbs if they were in a favorable position.

In bucking the logs, the usual procedure of cutting from the butt of the tree toward the top was followed. Sufficient wedges were used to complete cuts with a minimum of delay due to binding. In the smaller diameters, special attention was required to keep the logs from binding the saw. The situation was usually remedied by prying up under the log.

In recording the data, general descriptive measurements of the tree were noted. A stop watch was used to observe to the nearest hundreth of a minute the time required for every phase of the cutting from walking time to reach the tree, on through felling, limbing, and bucking. Stump height, log lengths, and scaling diameters were observed and recorded. Separate times were kept for each phase of the operation and recorded as to tree and log sizes. Delay times were the usual ones encountered on the job and do not include such items as traveling to and from work or rest periods.

The times recorded during the course of study were obtained by observing the complete operations on 80 randomly selected trees ranging from 8 to 18 inches in diameter. The pertinent information was recorded for each of these trees. The following activities were timed: felling, limbing, bucking, and moving from tree to tree.

The data collected were studied to determine the influence of tree size and log diameters on cutting time. Time values for each of the four activities were averaged by tree diameter groups as showin in the following tabulations. Travel time between trees was averaged out at 2.15 minutes.

Felling and limbing per d.b.h. class required the following time in minutes:

D.b.h.	Felling	Limbing
8	0.26	0.52
10	0.31	1.00
12	0.42	1.18
14	0.65	1.65
16	0.75	2.18
18	1.04	2.29

Average saw time required for bucking the various diameter classes (d.i.b.) was as follows:

Inches	Minutes
5	0.06
6	0.11
7	0.14
8	0.16
9	0.20
10	0.23
11	0.29
12	0.31
13	0.35
14	0.42
15	0.51
16	0.70
17	No data
18	0.76
19	0.82

These time values were later used to compute certain costs. In determining the overall costs involved in the operation, an effort was made to include all reasonable costs and to define them so that they could be adjusted to any specific operation.

The following cost items were used in the felling and bucking analysis. They are based on a two-man crew using a one-man chain saw and an axe. Interest and depreciation were computed on an investment of $450 for the chain-saw and other equipment. Hourly rates were based on 200 working days at 8 hours a day for a total of 1600 hours. Ten percent was added to labor costs to cover Social Security and other fringe benefits.

	Hourly Cost
Fixed Costs	
Interest at 6%	$0.02
Depreciation	.28
Maintenance, Posts, labor	.67
Insurance or risk	.02
Sub-total	$0.99
Operating Cost	
Gas, oil, wedges, etc.	$0.24
Hourly wages+10%	2.20
Total cost per crew hour	$3.43
Cost per man hour (rounded)	1.70

Some of the cost information prepared by Campbell in 1953 (See Bibliography) would be out of date at this time. We are more concerned, however, with the evaluation of research technique; therefore, the absolute values of the constants used are not important.

Other costs that were considered in the study were stumpage for sawtimber, pulpwood costs, sawlog skidding costs, and pulpwood loading and hauling costs.

The following tabulation, based on data from Campbell (1953), shows the actual costs associated with these factors.

Item	Cost
Sawtimber stumpage	$25.00/M
Sawlog skidding	7.50/M
Pulpwood	
Cut and stacked	8.00/cd.
Loading and hauling	4.00/cd.

The gross income derived from harvesting the trees and delivering the logs to the mill deck is based on a

price of $43.00 per thousand board feet log scale, (International ¼-inch rule). The pulpwood income amounts to $14.25 per cord.

This price represents standard cords of 128 cu. ft. By applying the above costs and income to the various systems of logmaking, net profits were figured for each combination of log lengths in each of the diameter classes.

These systems of log-making, each with its associated net profits, represent the alternatives among which choice is to be exercised. In this analysis, there were 103 of these alternatives. Because of the limited capacity of the 650 IBM Computer, however, only 18 logmaking systems were included, three for each tree-size class. These systems were selected as follows:

1. The three possible cutting methods that yielded the highest net profits were examined.
2. When these three methods could produce any of the standard log lengths, they were selected.
3. When some of the standard log lengths were not represented, successively less profitable methods were substituted until all standard log lengths could be produced from each tree-size class.

Thus, the three methods finally selected in each tree-size class would produce the highest net profits in each class consistent with complete representation of all log lengths in all classes. While other methods of editing the data for computation are possible, it seemed this method was least likely to bias the final results. This absence of bias means that the profit-maximizing solutions for the edited program will depart little, if any, from profit-maximizing solutions based on computation with all 103 alternatives.

Linear Programming of Log Production

The analysis considers a logging operator who has a tract of timber estimated to contain approximately 71,000 board feet. The distribution of tree sizes and their respective volumes is indicated in Table 1. From this fixed set of resources, the timber stand, he desires to cut logs to satisfy the sales restrictions dictated by the market he is to supply. There are an unlimited number of ways to accomplish this effectively, and linear programming enables him to choose *the* way that will give the largest profit.

If the logging operator had no sales restrictions and knew the exact net profit each "cut-up" system would yield, he would simply choose the most profitable way to cut the trees in each size class. This method of using his timber resources would certainly maximize the profits. It is evident, however, that such is not the case. If the logging crews cut only the most profitable logs, large amounts of resources would be left in the woods and never used. Further, the merchandising pattern of the lumber industry is such that lumber of all standard lengths are needed. Consequently, the logs from which the lumber comes must be assorted standard lengths. It is apparent that the logging crews must produce logs of each length rather than concentrating on the production of only those that return the most net profits.

The operator must consider certain restrictions and limitations imposed by the tract of timber, as shown below:

Tree classes Inches	Number of trees available
8	126
10	213
12	170
14	100
16	30
18	6

The resource limitations may be stated mathematically. In editing the data for computation, three cut-up methods for each tree-size class are selected. Considering only 8-inch trees as an example, the number of these trees cut up by the first method is represented by X_1, the number by the second method X_2, and the number by the third X_3. The inequality $X_1 + X_2 + X_3 \leq 126$ states that the number of 8-inch trees cut by the three methods cannot exceed the number available. In a similar way $X_4 + X_5 + X_6 \leq 213$ expresses the resource limitation on 10-inch trees. The entire system of restraints imposed by the limited stand of timber is expressed by the system of equations:

$$(1)\ X_1 + X_2 + X_3 \leq 126$$
$$(2)\ X_4 + X_5 + X_6 \leq 213$$
$$(3)\ X_7 + X_8 + X_9 \leq 170$$
$$(4)\ X_{10} + X_{11} + X_{12} \leq 100$$
$$(5)\ X_{13} + X_{14} + X_{15} \leq 30$$
$$(6)\ X_{16} + X_{17} + X_{18} \leq 6$$

The operator must also consider volume requirements and sales restrictions established by conditions in the market where the logs are sold. These restrictions are shown below.

Log length (Feet)	Sales restriction (Board feet)
16	Not more than 28,413
14	Not less than 14,206
12	Not more than 10,655
10	Not more than 10,655
8	Not more than 7,103

Market limitations in this case represent limitations imposed by the purchaser. These limitations were obtained from concentration yard operators handling the output of the mills studied. They may be stated mathematically in the following way. The variable X_1 through X_{18} introduced in the previous system of inequations represent the number of trees processed by each of the 18 cut-up methods included in the analysis. Consider now only 16-foot logs. Not all cutup methods yield this length log. Those that do are: Methods 3, 6, 7, 12, 13, 14, 18 which yield 25, 70, 135, 135, 115, 115, and 160 board feet, respectively.

Then the inequality $25X_3 + 70X_6 + 135X_7 + 135X_{12} + 115X_{13} + 115X_{14} + 160X_{18} \leq 28,413$ states that the total yield of 16-foot logs from all trees cannot exceed the sales maximum of 28,413 board feet. In a similar way, the inequality $40X_2 + 80X_1 + 20X_6 + 100X_8 + 55X_9 + 185X_{10} + 140X_{11} + 140X_{13} + 140X_{14} + 185X_{15} + 100X_{18} \geq 14,206$ states that the output of 14-foot logs has to be at least as great as the sales minimum of 14,206 board feet. The system of market limitations is represented by the inequations:

$$(7)\ 25X_3 + 70X_6 + 135X_7 + 15X_{13} + 15X_{14} + 160X_{18} \leq 28,413$$
$$(8)\ 40X_2 + 80X_1 + 20X_6 + 100X_8 + 55X_9 + 185X_{10} + 140X_{11} + 140X_{13} + 140X_{14} + 185X_{15} + 100X_{18} \geq 14,206$$
$$(9)\ 35X_1 + 15X_4 + 25X_5 + 40X_8 + 35X_{11} + 15X_{12} + 25X_{13} + 25X_{14} + 315X_{15} + 315X_{16} + 315X_{17} + 70X_{18} \leq 10,655$$
$$(10)\ 102X_3 + 15X_5 + 35X_6 + 15X_{10} + 20X_{11} + 10X_{14} + 80X_{15} + 90X_{16} + 75X_{17} + 55X_{18} \leq 10,655$$
$$(11)\ 20X_1 + 5X_2 + 10X_4 + 10X_5 + 10X_7 + 10X_9 + 10X_{11} + 10X_{13} + 25X_{15} + 15X_{17} + 10X_{18} \leq 7,103.$$

The logging contractor needs to choose an overall tree cut-up program that meets the limitations of his timber stand and the sawmill requirements for various log lengths. These conditions affecting his choice have been stated mathematically in the relations 1 through 11. Choice of values for variables X_1 through X_{18} represents an overall tree cut-up program. Any selection of these values which satisfies the 11 relations is a possible program for the logging contractor to follow.

Each tree has associated with it a net profit, depending upon the way it is cut into logs. For example, of the three ways of cutting 8-inch trees one would yield a profit of 0.37, the second 0.34 and the third 0.12 cents per tree.

Table 2.—PROFIT MAXIMIZING SOLUTION FOR LOG PRODUCTION PROBLEM

Method	Trees cut	Tree classes (inches)	Bd. ft. volume by log lengths 8′	10′	12′	14′	16′	Net profit by method
1	36	8	360	-----	1,260	-----	-----	$ 13.32
4	213	10	2,130	-----	3,195	17,040	-----	368.49
7	70	12	700	-----	-----	-----	9,450	130.20
9	100	12	1,000	3,500	3,500	5,500	-----	175.00
12	100	14	-----	-----	1,500	-----	18,500	260.00
15	30	16	750	2,400	-----	5,550	-----	100.80
16	3	18	-----	270	945	-----	-----	16.32
18	3	18	30	165	210	300	480	15.12
Totals			4,970	6,335	10,610	28,390	28,430	$1,079.25

Unit profits for all cutting methods can be computed from output and price data. In this case, the computations yield the following profit function:

$$\text{Profit} = .37X_1 + .34X_2 + .12X_3 + 1.74X_4 + 1.40X_5 + 1.19X_6 + 1.86X_7 + 1.78X_8 + 1.75X_9 + 2.76X_{10} + 2.63X_{11} + 2.60X_{12} + 3.38X_{13} + 3.37X_{14} + 3.36X_{15} + 5.44X_{16} + 5.30X_{17} + 5.04X_{18}.$$

It is seen that choice of value X_1 through X_{18} will determine the overall profit of the logging contractor.

Clearly now, the problem of the logging contractor becomes one of finding a set of cut-up processes that will maximize the profit function subject to the stated linear constraints. The most common procedure for solving linear programming problems of this type is the simplex technique. The simplex method consists first of selecting from the large number of cut-up methods a combination that will satisfy the linear restrain. It provides a step-by-step way of improving the selection of cut up methods until the profit-maximizing selection is reached. At this point, it becomes quite clear that no further improvement is possible.

Up to this point, the analysis has been confined to gathering data, selecting the eligible processes for scheduling, establishing restrictions, and formulating the basic inequalities and equalities.

Table 2 presents the profit-maximizing solution. This program produced 78,735 board feet of sawlogs and yielded a total net revenue of $1,079.25. In so doing, the program utilized 8 of the 18 cut-up methods which were available. All of the available timber was cut into sawlogs except 90 eight-inch trees. All 12- and 16-foot lengths were produced to their maximum specified capacities. The output of 14-foot logs was at the minimum allowed by the market restrictions. The output of 8- and 10-foot logs was less than the maximum amount the sawmill was willing to take.

A conspicuous feature of this profit-maximizing solution is that all of the available 8-inch trees were not cut into logs. This suggests there is a "bottleneck" in the established program that must be overcome in order to use all of the 8-inch trees and increase the total profit. Removing this "bottleneck" involves either changing sales restrictions or considering additional cut-up systems. As an illustration of the first possibility, the sales limitations on larger length logs could be raised to allow the production of more of the 12-, 14- or 16-foot logs. If this is done, the producer runs the risk of having to accept lower prices for the surplus volume of longer lengths. On the other hand, since the quantity of 8- and 10-foot logs is not near the maximum acceptable volumes, and since there is a surplus of 8-inch trees, the operator could provide an additional way of cutting 8-inch trees into 8- and 10-foot logs. Although this may mean lower net returns on the 8-inch trees, it may permit an increase in the total net profit.

Table 3 shows the results obtained by taking advantage of the second alternative of adding another method of cutting 8-inch trees into 8- and 10-foot logs. It presents the optimum program that resulted after the introduction of an additional method of cutting each of the 8-inch trees into one 8-foot and two 10-foot logs. Since this was the only change made relative to the program shown in Table 2, it is seen that adding Method 19 eliminates the "bottleneck". All of the standing timber in the tract has now been converted into sawlogs. Each of the requirements for 12-, 14- and 16-foot logs were fulfilled to their maximum capacities. However, the maximum specified capacities for the 8- and 10-foot logs were not completely attained. If there had been 65 more 8-inch trees available, each of these maximum capacities would have been produced.

Not only does this program cut all of the trees into logs in a way that satisfies all of the sales restrictions, but it produces 82,450 board feet of logs at a maximum net profit of $1,094.59. It should be noted that the original estimate for the volume of the fixed number of trees available was 71,032 board feet. Yet, the operator, following the production schedule called for by the profit-maximizing program in Table 3, produces 82,450 board feet in log scale. The increase above the original estimate represents a 9 percent overrun in volume recovery. This 9 percent increase is a "by-product" resulting from the inclusion of only the cutting methods which yield the highest board feet volume, as well as the highest net profits.

Out of a total of 19 different methods of cutting logs, only 9 are used. It is interesting to note here that methods 13 and 14, the two most profitable ways for cutting 16-inch trees, are not used. Instead, Method 15 is used to convert the entire supply of 16-inch trees into logs. It is unlikely that any conventional means of selecting a cut-up program for these trees would have included Method 15.

This illustrates an important characteristic of linear programming as compared with other ways of selecting cut-up schedules. Through a systematic consideration of all of the restraints affecting the logging contractor, profit-maximizing calculation is substituted for intuitive judgment.

Selected Bibliography

Bethel, J. S. and Cleon Harrell. 1957. The application of linear programming to plywood production and distribution. For. Prod. Jour. Vol. VII (10): 221–227.

Campbell, Robert A. 1953. Logging methods and costs in the Southern Appalachians. Southeastern For. Exp. Sta. Station Pa. per No. 30.

Dorfman, Robert. 1951. Application of linear programming to the theory of the firm. Univ. Calif. Press.

Henderson, A., and R. Schlaifer. 1954. Mathematical programming: Better information for decision making. Harvard Business Review. May–June. 73–100.

Koopmans, T. C. (ed.) 1951. Activity analysis of production and allocation. John Wiley and Sons, Inc., New York.

Slocum, G. K., and W. D. Miller. 1953. Virginia pine-reproduction, growth and management of the Hill demonstration forest, Durham County, North Carolina. N. C. Agr. Exp. Sta. Tech. Bul. No. 100.

Table 3.—OPTIMUM PROGRAM WITH ADDITIONAL CUTTING PROCESS (METHOD 19).

Method	Trees cut	Tree classes (inches)	Bd. ft. volume by log lengths 8′	10′	12′	14′	16′	Net profit per process
1	27	8	270	-----	945	-----	-----	$ 9.99
4	213	10	2,130	-----	3,195	17,040	-----	368.49
7	79	12	790	-----	-----	-----	10,665	146.94
9	91	12	910	3,185	3,185	5,005	-----	159.25
10	4	14	40	60	-----	740	-----	11.04
12	96	14	-----	-----	1,440	-----	17,760	249.60
15	30	16	750	2,400	-----	5,550	-----	100.80
16	6	18	-----	540	1,890	-----	-----	32.64
19	99	8	1,485	2,475	-----	-----	-----	15.84
Totals			6,375	8,660	10,655	28,335	28,425	$1,094.59

FUMIGANTS KILL

The Oak Wilt Fungus in Wood[1]

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SEVERAL COUNTRIES HAVE RESTRICTED IMPORTS OF OAK PRODUCTS FROM THE UNITED STATES *(9, 10)*, because there is evidence that oak wood may harbor the oak wilt fungus *(1, 2, 3, 4, 5, 6, 7, 8)*. Most of these countries permit imports if the material is certified as "wilt-free" and/or has been kiln dried. In general, kiln drying is costly and impracticable for veneer logs and timbers which are an important part of the total export. An efficient, non-destructive, cheaper method of disinfestation for large-dimension products is needed. Because gases penetrate wood easily, certain ones were studied in the laboratory as fungitoxic agents for the complete disinfestation of heavily infested wood. At least two promise to be effective and practical for commercial use.

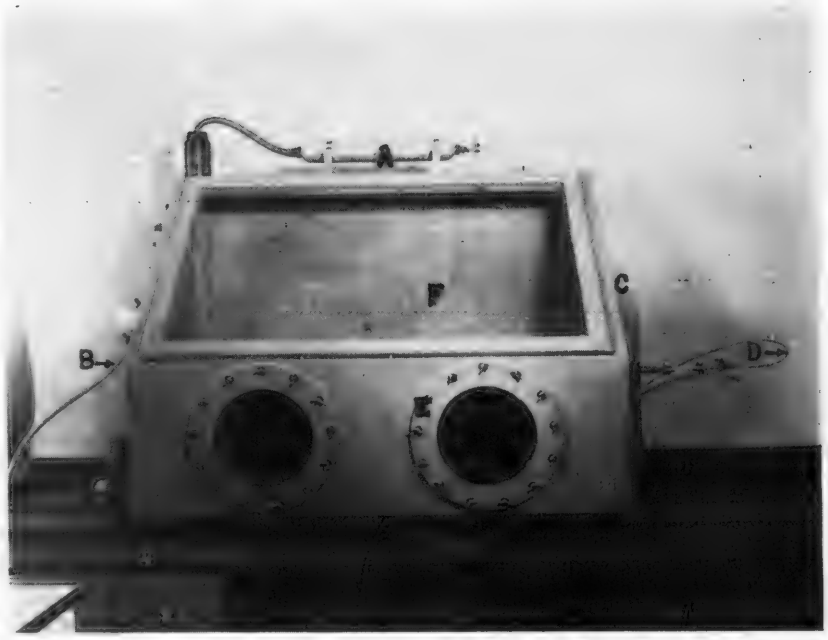

Fig. 1.—Chamber used for fumigation tests: A—air filter inlet, B—exhaust line, C—access door, D—gas inlet tube, E—access hole (via neoprene gloves), F—viewing window.

Many countries restrict imports of oak products from the U. S. because of oak wilt fungus. Here are tests to show that two chemicals—chloropicrin and methyl bromide—will kill all of the fungus in a 3-day fumigation period. Although tests were made on 4-inch stems, the two fumigants may hold promise for use on larger dimensions.

Materials and Methods

Fifteen commonly available chemicals, having known or surmised fungitoxic fumes, were selected for the tests (Table 1). Chemicals having fumes that are highly toxic to mammals, or are explosive, or difficult to handle were not tested since their use would be limited by such characteristics. Commercially unavailable or expensive chemicals were not used for the same reason. No work of this kind had been previously reported; therefore, a base of reference had to be selected. Because propylene oxide is used for sterilizing wood, it was selected as the basic chemical.

A specially constructed chamber was used in handling the fumigants and test materials during the tests (Fig. 1). Each fumigant was used as a solute in a gaseous solution with air as the solvent. The basic chemical, propylene oxide, is fungitoxic at 1.0 milliliter per liter of air space, and attempts were made to use all chemicals in their liquid states at this rate. Corrections were made to assure that enough of each chemical was added to provide 250 milliliter of active ingredient in the chamber which had an internal volume of approximately 250 liters. All of the chemicals, which are liquids at 70° F. and atmospheric pressure, were simply placed in the chamber. The gases were handled differently. Generally, 250 milliliter of the liquefied gases (cylinder pressures of 1300 to 1600 psi at 70° F.) were not completely absorbed by the air in the chamber. Therefore, the gases were injected from external cylinders until slight pressure was indicated by an attached gauge. At this point the atmosphere was considered to be saturated.

Three tests comprised a screening process, which permitted a progressive elimination of ineffective materials.

In the first of these tests, 20 ten-day old slants of *Ceratocystis fagacearum* (Bretz) Hunt on "V-8" agar were exposed to each of the fumigants in order to establish the specific fungitoxicity of each fumigant.

In the second test, each of the successfully fungitoxic chemicals was used to fumigate 10 small sections each of black oak *(Quercus velutina* Lam.) and white oak (*Q. alba* L.) stems. These sections, which were 1½ to 2 inches in diameter and 2¼ inches long with intact bark, had been sterilized in propylene oxide vapor and thoroughly infested by placing them on colonies of the fungus for 14 days.

In the third test, each fumigant which successfully killed the fungus in the small stem sections was used on 20 larger stem sections. These large sections were 3 to 4 inches in diameter, 8 inches long, and had intact bark. They were infested by the same

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[2] Maintained in cooperation with University of Missouri, Agricultural Experiment Station, Columbia, Missouri.

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Table 1.—FUMIGANT SPECIFICATIONS

Fumigant[1]	Trade name	Active ingredient Percent
Acetone	C. P. Acetone	100[2]
Carbon dioxide	Commercial grade carbon dioxide	99.5
Carbon monoxide	Commercial grade carbon monoxide	98.0
Carbon tetrachloride	C. P. carbon tetrachloride	100[2]
Chlorine	Chlorine	99.8
Chloropicrin	Larvacide chloropicrin	97.0
Ethylene dibromide	Dowfume W-40	41.0
	Dowfume W-85	83.0
Formaldehyde	Formaldehyde solution, U.S.P.	40[2]
Methanol	Methyl alcohol	80[2]
Methyl bromide	Dowfume MC-2	98.0
3,5-Dimethyltetrahydro-1,3,5,2H-thiadiazine-2-thione	Crag Mylone soil fumigant	95.0
Nitrogen	Water pumped nitrogen	99.6
1,2-Epoxypropane	Propylene oxide, Pract.	100[2]
Sodium methyl dithiocarbamate	Vapam soil fumigant	32.7
Xylol	Xylene Merck	100[2]

[1]Material and technical aid was supplied gratis by the following companies: The Dow Chemical Co., Midland, Mich.; Stauffer Chemical Co., New York, N. Y.; Union Carbide Chemicals Co., New York, N. Y.
[2]Approximate.

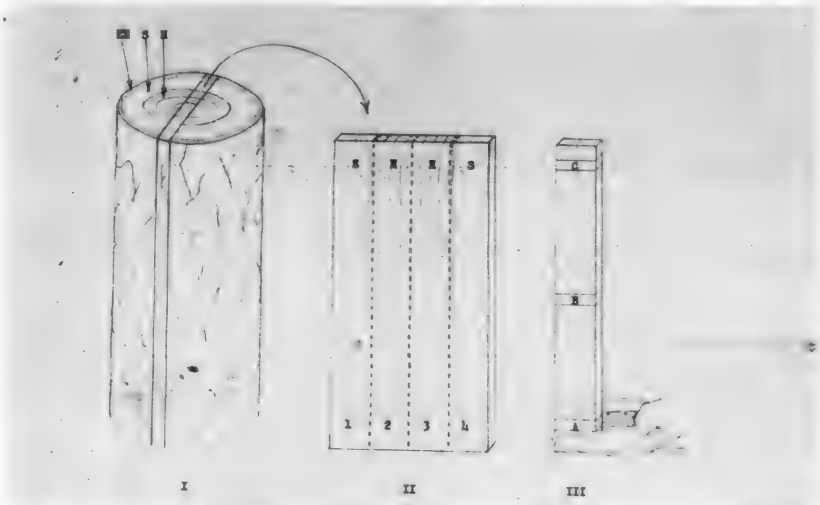

Fig. 2.—Method of sampling large stem sections. I—Whole stem section. Slab was removed from the central plane as indicated. Bk, bark; H, heartwood. S, sapwood. II—The removed slab was split along the dashed lines into 4 sticks (1, 2, 3, and 4). III—One of the 4 sticks. Samples were taken from A, B, and C with sterile shears. This provided 12 samples. The remaining 12 were obtained by removing a second slab at right angles to the first, through the remaining halves of the stem section, and repeating the preceding procedure.

method used on the smaller sections, except that 21 days of exposure to the colonies was necessary for thorough infestation. As previously discovered (5), the fungus had penetrated all sapwood and some heartwood at this time. Radially, ¾ of an inch to 1½ inches of sapwood and up to ¾ of an inch of heartwood were invaded.

Initially, the colonies or infested stem sections were exposed to each fumigant for 7 days. Finally, when certain fumigants were found effective at 7 days, the interval was reduced to 3 days.

In all tests untreated cultures served as checks.

The effectiveness of each fumigant was determined after fumigation by transferring colony samples or wood samples to fresh "V-8" media and incubating at approximately 25° C. for 14 days. Six mass transfers were made from each slant for this purpose. A ¼-inch thick slab was split from the center of each small stem section for the same purpose. Each large stem section was systematically sampled at 24 points (Fig. 2), and the samples were cultured. Throughout the study, incomplete kill by any fumigant at any point in the tests eliminated it from further testing. This was done because incomplete disinfestations would not assure that the fungus could not be carried in the wood in question.

During the entire procedure, the intent was to approximate the conditions that might prevail if freshly cut, infested oak wood were to be fumigated in the field, using a simple, non-pressurized chamber or a gas-tight tarpaulin.

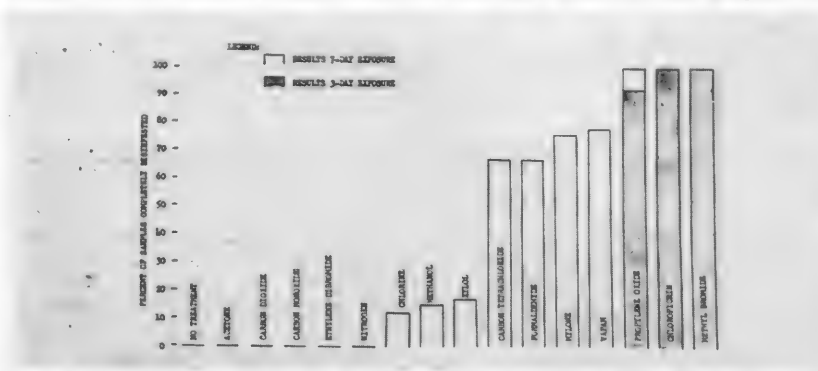

Fig. 3.—The relative effectiveness of each fumigant in disinfesting oak wood. Only those fumigants that successfully disinfested wood within 7 days were retested according to the 3-day exposure interval.

Results

Only chloropicrin and methyl bromide killed all of the fungus in all wood when 3-day exposure intervals were used (Fig. 3). With 7-day exposure intervals, chloropicrin, methyl bromide, and propylene oxide were successful. Carbon tetrachloride, formaldehyde, Mylone, and Vapam (these two trade names are used here for brevity) were effectively fungitoxic and penetrated well, but after 7 days of exposure the fungus occasionally could be reisolated from one or two sample sections from within the large stem sections. Chlorine, although toxic to the fungus, did not penetrate the wood well enough to bring about satisfactory disinfestation. Both methyl alcohol and xylol were ineffective as killing agents. Seven days of exposure to acetone, carbon dioxide, carbon monoxide, ethylene dibromide, or nitrogen did not kill the fungus in culture or in wood.

No noticeable undesirable side effects were produced on the wood by the successful fumigants.

Discussion

In general, the tests revealed that the disinfestation of heavily infested wood, using fumigants, is possible. Under natural conditions, infestations of the degree created for these tests are unlikely; therefore, the method appears to be a potential means of assuring that oak products are wilt-free. Because the successful fumigants are relatively cheap, available, and easy to handle, and because they do not require expensive or complicated equipment, they are apparently practical for the proposed use. In addition, this method will avoid the undesirable side effects of kiln drying logs or timbers.

The tests did not prove that these fumigants will disinfest large-dimension products, but their speeds of penetration and kill during the tests show that they have promise of doing so.

Of the fumigants tested, chloropicrin and methyl bromide are the best for this type of disinfestation. Propylene oxide may also be useful, but it is slightly less effective than either chloropicrin or methyl bromide. The other fumigants tested, unless used at high concentrations and/or for long exposure intervals, were ineffective in assuring that oak wood was wilt free.

Literature Cited

1. Brandt, W. H. 1953. Studies on the effect of Chalara fagacearum on oak wood and its effect on rates of rotting by associated wood-rotting fungi. (Abst.) Phytopath. 43(9): 467.
2. Englerth, G. H., J. S. Boyce, Jr., and E. R. Roth. 1956. Longevity of the oak wilt fungus in red oak lumber. Forest Sci. 2(1): 2–6.
3. Jones, T. W., and T. W. Bretz. 1955. Radial penetration of the oak-wilt fungus into the boles of diseased trees. Plant Dis. Reporter. 39(11): 872.
4. Merek, E. L., and C. L. Fergus. 1954. Longevity of the oak wilt fungus in diseased trees. Phytopath. 44(6): 328.
5. Partridge, A. D. 19__. The growth and survival of the oak wilt fungus in oak blocks. (Edited for Forest Sci.)
6. Spilker, O. W. 1953. The longevity of Endoconidiophora fagacearum in lumber and other wood products cut from diseased trees. (Abst.) Phytopath. 43 (9): 485.
7. Spilker, O. W., and H. C. Young. 1955. Longevity of Endoconidiophora fagacearum in lumber. Plant Dis. Reporter. 39(5): 429–432.
8. Young, H. C., and W. H. Brandt. 1953. Timber decay and deterioration observed in oak wilt experiments. Ohio Farm and Home Res. 38(280): 8–9.
9. U. S. Department of Agriculture. 1958. Certification of oak logs and lumber for export to foreign countries. Plant Quar. Memo. No. 635. U. S. Dept. of Agr., ARS, Plant Quar. Div., March 14.
10. U. S. Forest Service. 1958. Southeastern forest insect and disease newsletter No. 5. U. S. Dept. of Agr., Forest Serv., Southeast. Forest Expt. Sta., April.

Permeability of Douglas-Fir In Oregon[1]

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Wood from scattered mills was tested for permeability to air, creosote, and water. Permeability, which varied geographically, could not be predicted from density or growth characteristics.

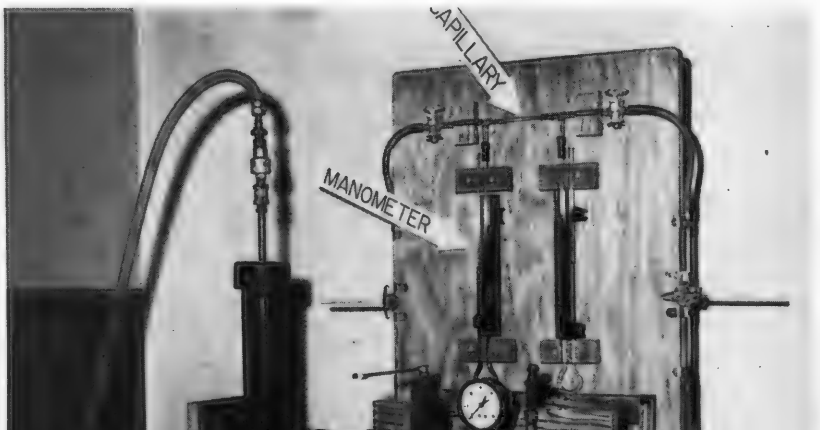

Fig. 1.—Apparatus used to determine rate of air flow through wood specimens that measured 1 inch along the grain. Incoming air to the specimen was regulated at 20 psi; exhaust air from the specimen was routed through the capillary and vented to the atmosphere. Pressure of exhaust air upstream from the capillary was read on a mercury or water manometer and converted to cc of air flow to a second.

THE FOREST PRODUCTS industries, in search of new and improved uses for wood, have learned to modify and even to "rebuild" wood to take advantage of, or enhance, its most desirable characteristics. To maintain, or develop, quality control during manufacture of forest products, one often must cope not only with processing conditions, but also with naturally occurring variation of the raw material.

One of the most perplexing problems of the wood-preserving industry is the varying resistance which wood of different species, or even of one species, may offer to impregnation. In some instances, the variations are associated with anatomical distinctions of the woods concerned; in other instances, the causes of recognized differences in permeability are obscure. Douglas-fir has been classified into two forms, or varieties, according to differences in morphology and environmental requirements (3)[2]. Heartwood of the Rocky Mountain form of Douglas-fir (variety *glauca*) is recognized as being less permeable than that

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[2] Numbers in parentheses refer to the Literature Cited at the end of this paper.

Fig. 2.—Numerical ratings used to define penetration of creosote or copper sulfate solution into 6-inch specimens of Douglas-fir.

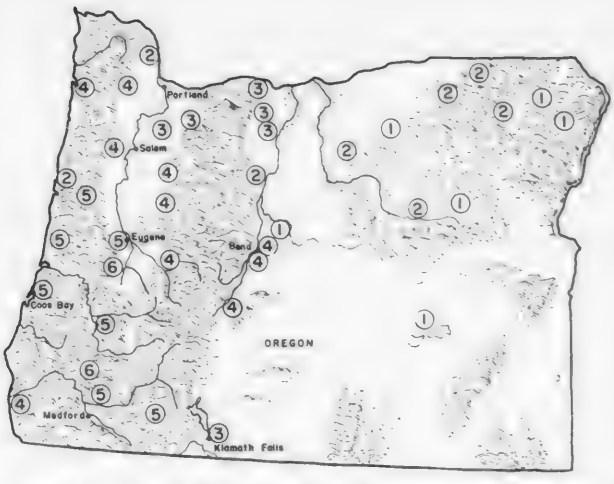

Fig. 3.—Location of some mills that supplied test material, and ratings of penetration of creosote into 6-inch specimens of oven-dried Douglas-fir heartwood as shown in Fig. 2.

of the Pacific Coast form (variety *menziesii*) (2). Work reported in this paper was limited to specimens of Douglas-fir wood from different areas in Oregon.

Procedure

Material: Douglas-fir studs collected from sawmills throughout Oregon were tested to evaluate permeability of the wood. Heartwood test material was collected from 29 mills during 1958; heartwood and sapwood from 18 other mills was collected during 1959.

Material collected during 1958 was received as three unseasoned, 14-foot pieces from each mill. Four test specimens 1.2 by 1.2 by 6 inches in size were cut from each of the ends of individual studs. One pair of side-matched specimens was oven-dried, a second pair was conditioned at 90° F. to a moisture content of 8 percent. One specimen of each pair was marked for impregnation with creosote, the other with water. The remaining central portion of each original piece was stored at 35° F for further study.

Material obtained during 1959 consisted of 2 unseasoned, or kiln-dried, 4-foot pieces of heartwood and 2 pieces containing sapwood from each of 18 mills. Cross sections cut near both ends of each piece were conditioned at room temperature to a moisture content of 10 percent before being tested for permeability to air flow along the grain. The remainder of each stick was cut into 1- by 1-inch by 6- and 18-inch specimens, which were oven-dried and used to evaluate permeability of the wood to creosote or to a copper sulfate-water solution. The 18-inch specimens were partially coated with a modified epoxy resin to exclude solution from other than one end-grain surface.

Tests of Wood Permeability: Permeability of wood specimens from various localities was evaluated by rate of air flow and by extent of liquid penetration along the grain.

The rate of air flow through wood was measured by means of the apparatus shown in Fig. 1. Specimens, carefully trimmed to 1-inch length along the grain, were subjected to air at a pressure of 20 pounds per square inch over a circular area of end-grain surface with a diameter of 0.625 inch. Rate of flow through the wood was measured in terms of air pressure at the "downstream" surface, and was expressed as cubic centimeters of air flowing through the apparatus in one second. Three areas usually were tested on each specimen.

Permeability of wood also was evaluated according to its ease of impregnation by creosote or aqueous solutions. Specimens were submerged in the solution and were subjected to pressure of 100 pounds per square inch for 30 minutes. Temperature of the impregnating solutions used in tests in 1958 averaged 170° F for creosote and 70° F for water; all later tests were made either with creosote or with a 10 percent solution of copper sulfate, both heated to 120° F.

Penetration of solution and values for retention were the criteria used to assess ease of impregnation of the wood. Values for retention were based on volume and increase in weight of individual specimens during treatment. Penetration of impregnated specimens was evaluated after splitting them across the growth rings and along the grain to expose a radial face. Areas that had been penetrated by copper suplfate darkened with H_2S gas, or by creosote, were detected easily. Penetration into 6-inch specimens was estimated visually according to comparative ratings shown in Fig. 2. Penetration into longer, coated specimens was measured along the grain from the uncoated end to a point where an estimated 50 percent of the cross section had been penetrated.

Studies of Wood Anatomy and Extractive Content: Eighteen sticks, six apiece of refractory, permeable, and semi-permeable heartwood, had been reserved for comparative study of their anatomy and extractive content.

Gross anatomical features, including growth rate and percentage of summerwood, were examined. The average values for specific gravities (oven-dry weight, unseasoned volume) of the three types of heartwood also were compared.

Investigation of the minute structure of specimens was limited to a cursory microscopical examination of permeable and refractory heartwood enlarged 130 diameters. In further study of similar material, currently in progress in the Forest Products Department at Oregon State College (4), the lengths of mixed summerwood and springwood fibers (tracheids) and diameters of the lumens of springwood fibers have been measured.

Small particles of permeable and refractory heartwood that had been passed through a 35-mesh screen, and retained on a 60-mesh screen, were boiled for 8 hours to remove alcohol,

benzene-soluble extractives. The loss in weight of the particles, expressed as percent, based on the dry, unextracted weight of wood, was calculated after 2, 4, and 8 hours of boiling in alcohol-benzene (33–67 mixture by volume).

Results

Rate of air flow along the grain of wood was not a reliable index of potential longitudinal penetration of creosote. Wood that was either very resistant, or permeable to penetration of creosote, however, could be detected by respectively low or high rates of air flow. Refractory heartwood from northeastern Oregon permitted little or no air flow (average, 0.14 cc per second); the most permeable heartwood and sapwood from western Oregon passed more than 10 cc of air per second (average, 11.6).

Average values for penetration of creosote into Douglas-fir heartwood from various sources in Oregon are mapped in Fig. 3 by ratings shown in Fig. 2. Results of 1958–59 surveys indicated that heartwood from western Oregon varies more in permeability, but is generally more treatable (permeable) than is heartwood from northeastern areas of the State.

Difficulties in procurement reduced the number of sapwood specimens, but the available data allow limited observations of sapwood permeability. Sapwood was normally more permeable than was heartwood from the same source, but sometimes was less permeable than heartwood from other sources.

The copper sulfate solution usually penetrated more deeply than did creosote into wood of low permeability. The relationship between average values for penetration of creosote and of copper sulfate solution into end-matched specimens is shown in Fig. 4.

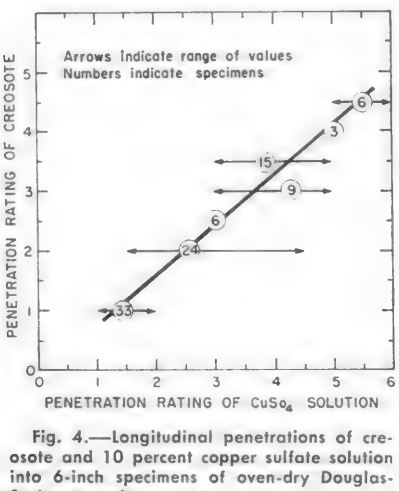

Fig. 4.—Longitudinal penetrations of creosote and 10 percent copper sulfate solution into 6-inch specimens of oven-dry Douglas-fir heartwood.

Table 1.—LUMEN DIAMETER AND FIBER LENGTH IN DOUGLAS-FIR

No. of pieces	No. of observations	Fiber length[1] Mm	Lumen diameter[2] Microns	Section
Permeable heartwood				
12	180	5.59		
3	327	----	35.61	Tangential
3	241	----	40.32	Radial
Refractory heartwood				
12	200	3.68		
4	539	----	26.69	Tangential
4	221	----	27.96	Radial

[1]Summerwood and springwood.
[2]Springwood only.

Differences in gross anatomical features were not indicative of differences in permeability of specimens. Both permeable and refractory heartwood had from 10 to 30 rings per inch. Volume of summerwood was not related clearly to penetration or retention of creosote in the wood. The average values for specific gravity of refractory, permeable, and semi-permeable heartwood were 0.48, 0.49, and 0.48, respectively.

The lumens of springwood tracheids, examined in tranverse section at 130 X, appeared to be largest in specimens of permeable heartwood. In further study, now in progress in the Forest Products Department at Oregon State College, measurements of lumen diameter in springwood have supported this observation. Currently available data are summarized in Table 1.

Small particles of permeable and refractory heartwood lost the same percentage of their weight of alcohol-benzene solubles, but differed in rate of extraction. Both had lost equally, after 8 hours of boiling, about 5 percent of their initial calculated oven-dry weight. The rate of weight loss of refractory heartwood was about twice as rapid as that of permeable heartwood during the first 2 hours of boiling.

Discussion

The results of these surveys clearly indicate that Douglas-fir heartwood from eastern Oregon is generally much less permeable than is material from the western half of the State. This seemingly represents a known difference between permeability of Pacific Coast and Rocky Mountain forms of Douglas-fir.

Penetration of creosote into refractory heartwood was not improved greatly by extending the period of pressure treatment; attempts to improve penetration by use of this method were most beneficial when used on semi-permeable wood.

Permeability may be associated with both the minute structure and the chemistry of wood. The small average size of tracheids of very refractory heartwood from eastern Oregon may be a morphological characteristic of what is presumably the Rocky Mountain type of Douglas-fir. The effect of tracheid size on permeability of the wood was not studied. The effect of pit aspiration on penetration of preservatives in Douglas-fir has been studied by other investigators, who have reported conflicting evidence of direct as well as negligible effects (1, 5). Work done at the Oregon Forest Research Center has shown that removal of extractives from refractory heartwood increased its permeability to water and pulping liquor greatly.

Suppositions made in the above paragraph follow observations made on only six specimens each of the most refractory and permeable heartwood tested, and are to be viewed with caution until substantiated by further evidence.

Literature Cited

1. Griffin, Gertrude J. Bordered Pits in Douglas-fir. A Study of the Position of the Torus in Mountain and Lowland Specimens in Relation to Creosote Penetration. Journal of Forestry. 17:813–822. 1919.
2. Hunt, G. M., and G. A. Garratt. 1953. Wood Preservation. 2nd ed. New York: McGraw–Hill Book Co., Inc.
3. Isaac, L. A., and E. J. Dimock II. 1958. Silvical Characteristics of Douglas-fir var. menziesii. (Silvical Series No. 9). Pacific Northwest Forest and Range Experiment Station. U. S. Dept. of Agr., Forest Service. Portland, Oregon.
4. Krahmer, R. Lee. 1960. Some Anatomical Features Relating to Permeability of Douglas-fir Wood. Thesis written for M. S. degree. Forest Products Department, School of Forestry, Oregon State College, Corvallis.
5. Stone, D. C. 1936. Penetration of Preservatives in Douglas-fir as Affected by the Position of the Tori in the Pit-Pairs. Thesis written for M.S. degree. College of Forestry, University of Washington, Seattle.

A Method of Charcoal Analysis[1]

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THE CHARCOAL INDUSTRY provides a positive means for the utilization of low-value forest wood and mill residues. Both hardwood and softwood raw material can be converted to charcoal in various types of kilns or by chemical processing, in which there is recovery of both charcoal and associated byproducts.

Production has expanded markedly during recent years, with by-product facilities still producing more charcoal than do kilns. Kiln production is represented by hundreds of both small and large units operating singly or batterywise. Product diversification is apparent also in the rapid expansion of plants for briquetting charcoal. (See Figure 1.)

Because of the wide range of production methods employed, charcoal quality will not always be uniform nor consistent with the established levels for general market acceptance. For this reason, there is a definite need for unified methods of charcoal analysis for evaluating the products.

Most of the present methods are based on ASTM methods for coal and coke (D–271–48; D–346–35). Various modifications of these and other methods are used. The method described here is intended specifically for charcoal. It employs equipment found in most laboratories, and is adapted to routine analyses of a large number of samples. It is designed to give accurate results for moisture, volatile matter, ash, and fixed carbon.

Since this new method differs from ASTM methods D–271–48 and D–346–35 in several details, data for duplicate determinations on 100 samples were analyzed statistically. The samples were random samples of charcoal obtained from various sources in different parts of the country. The results were obtained by two analysts over a period of several months. Standard deviations of duplicates were: moisture, 0.06; volatile matter, 0.25; and ash, 0.07.

Fig. 1.—Locations of charcoal and briquetting operations.

Because of the wide range of production methods used by the charcoal industry, quality of the finished product does not always meet established levels for general market acceptance. This method of analysis will give accurate results for moisture, volatile matter, ash, and fixed carbon.

Four samples of charcoal were selected for repeated analysis. The selected samples were hardwood charcoals with volatile contents of 12, 15, 20, and 27 percent. Data for the repeated analyses on these four samples are shown in Table 1. Since the stability of the values for volatiles in stored, ground charcoal is unknown, the data were collected over a period of approximately 2 months. The data indicate that, during this time interval, volatility values remained constant for samples stored in sealed containers at room temperature. The data also demonstrate that the accuracy and reproducibility of the method are acceptable for establishing the quality of charcoal and for determining the effects of variables in production.

The four ground samples (Table 1) were submitted to two laboratories of large independent producers of charcoal for analysis by their methods. Results are shown in Table 3. It can be seen that agreement is good.

In view of the data shown in Tables 1, 2, and 3, the following procedure for the analysis of charcoal is outlined. By this procedure, 30 samples in duplicate (60 complete determinations) can be carried out by one analyst in 2 days.

Procedure for the Analysis of Charcoal

Sample Preparation: For the analysis to have value and meaning, a representative sample must be selected. This selection may be carried out according to ASTM methods for sampling of coal (D–271–48; D–346–35). Samples will normally be air-dry charcoal lumps or briquettes. Rain-soaked or wet samples should be spread out to air dry before they are analyzed. For determining the moisture content of the charcoal as received, the sample should be ground to pass a coarse screen such as No. 20 U. S. Standard Sieve, since heat generated by excessive grinding would cause loss of moisture. For the determination of volatile matter, a more finely ground sample is required. All of the selected sample should be ground; no part of the sample is to be rejected.

A Wiley mill, size No. 2 with a 1-millimeter screen, was used to give the screen analysis shown in Table 2. Three hundred grams of charcoal were ground in less than 5 minutes. Longer grinding times resulting from the use

The Authors: Wayne Moore is in charge of FPL's Section of Analytical Chemistry; Edward Beglinger has worked closely with carbonization research. Both are chemists.

[1] A contributed paper received April 27, 1960; approved for publication June 17, 1960.
[2] Maintained at Madison, Wisconsin, in cooperation with the University of Wisconsn.

Table 1.—REPEATED CHARCOAL ANALYSES

Date	Moisture Percent	Moisture Average	Volatile Percent	Volatile Average	Ash Percent	Ash Average	Moisture Percent	Moisture Average	Volatile Percent	Volatile Average	Ash Percent	Ash Average
	Sample I						Sample II					
1-16-58	1.83		12.53		4.42		1.85		15.67		2.88	
	1.83		11.45		4.38		1.88		15.35		2.81	
		1.83		11.99		4.40		1.86		15.51		2.84
1-20-58	1.92		11.52		4.36		1.92		15.29		2.79	
	1.87		11.94		4.44		1.91		15.55		2.76	
		1.90		11.73		4.40		1.92		15.42		2.78
1-27-58	1.71		12.72		4.51		1.84		15.62		2.82	
	1.74		11.47		4.49		1.81		15.71		2.86	
		1.73		12.10		4.50		1.82		15.66		2.84
2- 3-58	1.84		12.84		4.48		1.95		15.57		2.92	
	1.83		11.41		4.49		1.96		15.66		2.87	
		1.84		12.13		4.49		1.96		15.62		2.90
2-10-58	1.88		11.80		4.47		1.93		15.18		2.97	
	1.91		11.15		4.44		1.92		14.94		2.93	
		1.90		11.48		4.46		1.92		15.06		2.95
2-17-58	1.84		11.36		4.47		1.95		15.30		2.80	
	1.85		11.48		4.39		1.91		15.66		2.81	
		1.85		11.42		4.43		1.93		15.48		2.80
2-24-58	1.59		12.44		4.30		1.66		15.68		2.83	
	1.56		11.69		4.30		1.63		15.56		2.76	
		1.58		12.07		4.30		1.64		15.62		2.80
3-27-58	1.84		12.19		4.41		1.87		15.67		2.86	
	1.82		11.91		4.50		1.88		15.16		3.12	
		1.83		12.05		4.46		1.88		15.42		2.99
Std. Dev.		.107		.288		.063		.099		.191		.077
	Sample III						Sample IV					
1-27-58	----		-----		----		2.77		26.75		2.33	
							2.76		27.03		2.30	
								2.76		26.89		2.32
2- 3-58	2.00		19.73		1.88		2.92		27.06		2.29	
	1.98		19.98		1.91		2.88		27.27		2.22	
		1.99		19.86		1.90		2.90		27.16		2.26
2-10-58	1.99		19.83		1.95		3.05		26.49		2.33	
	2.03		19.59		1.89		2.97		26.59		2.31	
		2.01		19.71		1.92		3.01		26.54		2.32
2-17-58	1.98		19.77		1.84		3.04		26.18		2.24	
	1.99		19.89		1.95		3.04		26.07		2.21	
		1.98		19.83		1.90		3.04		26.12		2.22
2-24-58	1.55		20.31		1.85		2.48		27.10		2.11	
	1.54		20.10		1.84		2.46		27.07		2.13	
		1.54		20.20		1.84		2.47		27.08		2.12
3-27-58	1.94		20.31		1.92		2.91		26.76		2.18	
	1.94		20.18		1.86		3.04		27.11		2.22	
		1.94		20.24		1.89		2.98		26.93		2.20
Std. Dev.		.197		.240		.027		.215		.391		.075

of a finer screen or dull knives should be avoided because of the possibility of generating heat, which in turn causes a loss of volatile material. Excessive grinding will also produce a large amount of fine particles (smaller than 100 mesh, U. S. Standard Sieve). These fine particles may be swept out of the crucible during the rapid evolution of gases in the determination of volatile matter, and thus cause errors. Because over-size particles can result in low values for volatiles, particles larger than No. 20 U. S. Standard Sieve should be avoided. The ground samples should be stored in airtight containers such as screw-top bottles. The samples should be well mixed by shaking before they are weighed. "Jack stones" can be used to facilitate mixing.

Steps in Analysis: Analyses are carried out in duplicate, according to the following steps:

1. A muffle furnace that will control temperatures of 750° ± 5° C. and 950° ± 5° C. is required. Heat the muffle furnace to 750° C. and place previously ignited[3]—porcelain crucibles (41 millimeters × 37 millimeters) and lids in furnace for 10 minutes.

2. The crucibles are cooled in desiccator for 1 hour.

3. Weigh crucibles and add an accurately weighed (to 1/10 milligram) sample of approximately 1 gram of charcoal.

4. For moisture content, place samples in oven at 105° C., and dry for 2 hours.

5. Remove dried samples from oven and cool in desiccator for 1 hour and weigh.[4]

6. For the determination of volatiles, heat muffle furnace to 950° C.

7. The crucibles, with lids in place and containing the samples used for the moisture determination, are preheated as follows: With furnace door open, for 2 minutes on the outer ledge of the furnace (300° C.) and then 3 minutes on the edge of the furnace (500° C.).

8. The samples are then moved to the rear of the furnace for 6 minutes with the muffle door closed. The samples are watched through a small peephole in the door of the furnace. If sparking occurs, results will be in error. If the sparking sample does not check the results of its non-sparking duplicate within ± 0.5 percent, the analyses must be repeated.

9. The samples are removed and placed in a desiccator for 1 hour and weighed.

Fig. 2.—Nichrome wire baskets for handling covered crucibles.

[3] In practice, crucibles from previous determinations are used.

[4] The sample shall be considered oven dry when the decrease in weight of consecutive weighings is 0.0005 gram or less. Successive drying periods shall not be less than 1 hour.

Table 2.—SCREEN ANALYSIS OF CHARCOAL SAMPLES GROUND IN WILEY MILL

Screen size[1]	Sample number I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	Averags of 15 samplee
	Percent of Sample Retained on Smaller Screen															
Plus 20	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0.05
20 x 40	18.2	16.9	12.6	12.0	11.4	13.5	13.2	12.6	12.2	11.0	15.4	15.9	16.1	17.1	17.9	14.40
40 x 60	15.8	16.2	22.0	13.6	24.4	16.9	21.4	21.0	21.1	18.7	19.9	17.6	18.6	17.0	16.8	18.73
60 x 80	6.4	6.9	8.6	7.5	8.4	7.2	7.7	8.9	2.9	7.2	6.8	7.1	6.6	6.4	5.8	6.96
80 x 100	2.3	2.1	1.7	2.5	6.7	4.4	5.5	6.1	4.9	1.6	3.3	3.5	1.6	2.6	2.1	3.40
Minus 100	57.3	57.9	55.1	64.4	49.1	58.0	52.2	51.4	58.1	61.5	54.6	55.9	57.1	56.9	57.4	56.46

[1]U. S. Standard Sieve.

10. For ash determination, place the lids and the uncovered crucible containing the sample used for the volatile determination in the muffle furnace at 750° C. for 6 hours.

11. The crucibles with lids in place are cooled in a desiccator for 1 hour and weighed. Burning of the sample is repeated until successive 1 hour periods of heating result in a loss of less than 0.0005 gram.

12. Computations:

A. Moisture percent $=$ $\frac{\text{loss in weight} \times 100}{\text{weight of air-dry sample}}$

Report results to first decimal place. Moisture values for duplicates should agree within 0.1 percent.

B. Volatile percent $=$ $\frac{\text{loss in weight} \times 100}{\text{weight of oven-dry sample}}$

Oven-dry weight $=$ weight of air-dry sample minus moisture. Report results to first decimal place. Volatile values for duplicates should agree within 0.5 percent.

C. Ash percent $=$ $\frac{\text{weight residue} \times 100}{\text{weight of oven-dry sample}}$

Report results to first decimal place. Ash values for duplicates should agree within 0.1 percent. Note: All results except moisture are reported on oven-dry basis.

Table 3.—ANALYSIS OF CHARCOALS BY THREE LABORATORIES

	Forest Products Laboratory	Independent laboratory A, Analyst 1	Analyst 2	Analyst 3	Analyst 1	Analyst 2	Analyst 3	Independent laboratory B[1]
	Sample No. I							
Moisture	1.82	1.7	1.7	1.7	----	----	2.4	1.3
Volatile	11.99	11.7	10.9	11.1	11.4	11.2	10.8	10.5
Ash	4.45	----	4.3	----	----	----	----	4.6
Fixed carbon	83.56	----	84.8	----	----	----	----	84.9
	Sample No. II							
Moisture	1.89	1.4	1.5	1.5	----	----	2.3	1.4
Volatile	15.55	15.7	14.9	15.0	15.7	15.7	14.9	15.0
Ash	2.84	----	2.7	----	----	----	----	2.8
Fixed carbon	81.61	----	82.4	----	----	----	----	82.2
	Sample No. III							
Moisture	1.99	1.8	1.8	1.8	----	----	----	1.6
Volatile	19.86	20.1	19.1	20.0	19.8	19.9	----	20.3
Ash	1.90	----	1.8	----	----	----	----	1.8
Fixed carbon	78.24	----	79.1	----	----	----	----	77.9
	Sample No. IV							
Moisture	2.83	2.8	2.7	2.7	----	----	----	2.2
Volatile	27.03	27.1	26.5	26.5	27.2	27.3	----	27.6
Ash	2.29	----	2.2	----	----	----	----	2.5
Fixed carbon	70.68	----	71.3	----	----	----	----	69.9

[1]Data recalculated so that volatile, ash, and fixed carbon are also on the ovendry basis.

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To A Water-Soluble Preservative And Its Components[1]

C. MADHOSINGH
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An original contribution in the neglected field of interrelations between organisms in their attack on preservative-treated wood. Laboratory-proved preservatives are subjected to various additional natural factors when used in the field.

INFORMATION CONCERNING the tolerance of fungi to toxic chemicals is widespread in the literature. Most of this information deals with fungi of direct economic significance. When preservatives that have been tested against these organisms are used in the field, they are subjected to various natural factors that generally are not taken into consideration in laboratory tests.

The effect of other organisms, associated with the test organism, is a factor that should be considered in the critical evaluation of the preservative capacity of chemicals. The associated organisms may be of little apparent significance, yet they may modify the physiology of the prime organism or the toxic capacity of the preservative substances to such an extent as to render the treatment ineffective.

Coprinus micaceus Fr., a wood-decaying basidiomycete, and *Fusarium oxysporum* (Schl.) em. Snyder and Hansen[2] were found to be associated in white birch and poplar fence posts that were treated with a preservative mixture.[3] At the end of 8 years in an experimental plot, it was found that 90 percent of the treated posts had failed because of decay, apparently caused by *C. micaceus*. This was the only wood-decaying organism isolated, and was obtained from 88 percent of the rotted posts, while *F. oxysporum* was isolated from 67 percent of these posts.

The object of this study was to find the lethal and minimal growth concentrations of the preservative mixture and of its individual components for the two fungi isolated from the treated fence posts. For comparative purposes, two other organisms, *Polyporus adustus* Willd. ex Fr., a typical white-rot fungus, and *Lenzites saepiaria* (Wulf ex. Fr.) Fr., a brown-rot fungus, were included in some of the toximetric studies.

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Materials and Methods

The basal medium used in all the tests consisted of 2 percent malt extract and 2 percent bacto-agar in tap water. Concentrations of the preservative were expressed as a percentage of the solid material in the medium (weight to volume). All treatment chemicals were added before sterilization of the medium except potassium dichromate, which was added after the medium had been sterilized. Twenty-five cc. of medium were added to each Petri plate. The plates used were 90 mm. in diameter and 15 mm. deep. They were inoculated centrally with an agar plug, 6 mm. in diameter, obtained from the growing periphery of a 10-day-old culture of the particular fungus. The cultures were incubated at 80° F. and 70 percent relative humidity. There were four replicates in each treatment, and radial measurements of growth were made in millimeters periodically during the period of incubation.

When two-component salts were used in combination in a treatment, the concentration of each salt, expressed as a percentage, was the same in the final medium. The lethal concentration refers to the concentration of the particular salt, or combination of salts, expressed as a percentage of the medium (weight to volume), at which growth failed to take place within a period of five days, when the original plug inoculum or inhibited peripheral mycelium was replanted on untreated malt agar. The minimal growth concentration refers to the highest concentration of the particular chemical treatment at which growth took place.

Observations and Results

In medium containing the complete preservative, it was found that there was progressively less growth of *C. micaceus* as the concentration of the preservative increased from 0.03 to 0.11 percent. At the lower concentrations (0.006 and 0.01 percent, the growth of the organism was stimulated to a small extent. On the seventh day after planting, growth on the untreated medium was an average of 10 mm. less than the radial growth at the lower concentrations. Minimal growth occurred at the 0.02 percent concentration of the preservative mixture, while the organism was killed at the 0.15

[1] A contributed paper, received March, 1960. from the Forest Products Laboratories of Canada, a Division of the Forestry Branch, Department of Northern Affairs and National Resources.

[2] Identified by Dr. W. L. Gordon, Canada Department of Agriculture, Winnipeg, Manitoba.

[3] Composition: sodium fluoride 34%, potassium dichromate 34%, sodium arsenate 25%, and 2,4-dinitrophenol 7%.

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percent concentration. There was also stimulation in the growth of cultures of *F. oxysporum* at the lower concentrations of the preservative (0.006 and 0.01 percent). With these treatments, the culture plates were covered (over 45 mm. radial growth) by the seventh day after inoculation, whereas untreated controls attained a radial growth of only 38 mm. during this period. In addition, it was noted that there was an initial "lag" period of very slow growth at concentrations between 0.03 and 0.1 percent, and that this period increased as the concentration of the preservative in the substrate increased. The fungus showed only a trace of growth on medium containing 0.5 percent of the preservative, and was killed at the 0.58 percent concentration.

Both *P. adustus* and *L. saepiaria* were less tolerant of the complete preservative than was the *Fusarium*. These organisms were killed at the 0.11 percent concentration. The minimal growth concentration for *P. adustus*, was 0.04 percent and that for *L. saepiaria* was 0.06 percent.

Studies of the growth of the fungi in medium containing the individual components of the preservative showed that the minimal growth concentration of sodium fluoride for *C. micaceus* was 0.1 percent, and the lethal concentration was 0.15 percent. For *F. oxysporum* these figures were 0.52 and 0.88 percent, respectively.

The growth rate of *P. adustus* apparently was not altered by the sodium fluoride treatments between the 0.0005 and 0.1 percent concentrations. It was inhibited, however, at the 0.2 percent dosage, and replants from the periphery of the colonies showed that this concentration was also lethal to the organism. *L. saepiaria* showed stimulation in growth at concentrations from 0.001 to 0.05 percent of sodium fluoride when compared with growth on the untreated control plates. Five days after inoculation, cultures on the control plates had an average radial growth of 17 mm. At this time, cultures at the 0.001 percent concentration had an average radial growth of 30 mm. and those at the 0.05 percent concentration had an average growth of 20 mm. There was no growth at the 0.1 percent treatment and the organism was killed at the 0.15 percent concentration.

Concentrations of potassium dichromate, ranging from 0.0005 to 0.01 percent, had very little apparent effect on the growth of *C. micaceus*. Minimal growth occurred at the 0.05 percent concentration and the lethal dosage was 0.1 percent. *F. oxysporum* demonstrated the characteristic initial period of very slow growth in medium containing this salt. Minimal growth occurred at the 0.3 percent concentration while the lethal dosage was over 0.5 percent. It can be seen from Fig. 1 that although the minimal growth concentrations of the chromate salt for *P. adustus* and *L. saepiaria* were low (0.04 and 0.06 percent respectively), the corresponding lethal dosages were relatively high, being 0.2 and 0.5 percent respectively.

What This Research Means

The relatively wide range of tolerances to toxic compounds by fungi inevitably results in some treated woods becoming vulnerable to attack and deterioration. Moreover, the natural relationships between the wood-decaying fungi and other organisms in their environment could alter quite considerably the tolerances of these organisms to treated wood and the effectiveness of the treatment itself. These symbiotic associations should be considered in the toximetric evaluation of fungicides to be used in the field.

C. micaceus proved to be very tolerant of the arsenate salt, and grew at a normal rate from the 0.0005 up to the 0.01 percent concentrations. There was a minimal amount of growth at the 0.4 percent concentration, and the organism was killed at the 0.5 percent concentration. *F. oxysporum* was found to be even more tolerant of this chemical. Growth occurred even at the 1 percent concentration, the highest dosage used in the experiments. The minimal growth concentration of sodium arsenate for *P. adustus* was 0.01 percent and the lethal dosage was 0.2 percent. The lethal and minimal growth concentrations for *L. saepiaria* was 0.5 and 0.14 percent respectively.

The lower concentrations of 2,4-dinitrophenol, ranging from 0.0005 to 0.001 percent, had no stimulatory effect on *C. micaceus*, and growth appeared to be normal. The organism was very susceptible to only slightly higher concentrations of this chemical however, being inhibited in growth at the 0.004 percent concentration and being killed at the 0.006 percent treatment. *F. oxysporum* was found to be about 10 times more tolerant of the phenol than was the *C. micaceus*. Minimal growth of the *Fusarium* occurred at the 0.02 percent concentration, while the 0.05 percent concentration was found to be lethal. The minimal and lethal growth concentrations for *P. adustus* were 0.01 and 0.02 percent, respectively. Minimal growth of *L. saepiaria* occurred at the 0.008 percent concentration of the dinitrophenol, and the lethal dosage was 0.01 percent.

In experiments with sodium fluoride-potassium dichromate mixtures, which ranged in concentration from 0.005 to 0.5 percent, it was found that *C. micaceus* was inhibited at the 0.2 percent dosage while the organism grew at a virtually normal rate up to the 0.05 percent concentration. The fungus was killed at the 0.5 percent concentration. *F. oxysporum* was less tolerant of this mixture, being inhibited in growth at the 0.1 concentration and being killed at the 0.2 percent treatment.

Over the same concentration range of sodium arsenate-sodium fluoride treatments, *C. micaceus* showed minimal growth at the 0.1 percent concentration and was killed at the 0.2 percent concentration. *F. oxysporum* demonstrated a greater tolerance for this mixture, with minimal growth occurring at the 0.5 percent concentration. The dosage lethal to this organism was over 1 percent.

C. micaceus grew normally on mixtures of potassium dichromate and sodium arsenate that ranged in concentration from 0.0005 to 0.01 percent. There was a minimal amount of growth at the 0.05 percent concentration, and the lethal dosage was 0.1 percent. *F. oxysporum* was stimulated in the same concentration range of the mixture at which *C. micaceus* grew normally. Above the 0.01 percent dosage, however, there was a definite "lag" period before growth was initiated. Minimal growth occurred at the 0.2 percent concentration, and the lethal dosage was 0.5 percent of the mixture.

Experiments involving the growth of *C. micaceus* in the sodum arsenate-dinitrophenol mixture showed that there was minimal growth at 0.01 percent concentration, and that the organism was killed at the 0.02 percent concentration. The minimal growth and lethal concentrations were 0.05 percent and 0.1 percent, respectively, for the *Fusarium* fungus.

The minimal growth and lethal concentrations of the potassium dichromate-dinitrophenol mixture were 0.02 and 0.05 percent for *C. micaceus* and 0.1 and 0.18 percent, respectively, for *F. oxysporum*.

Media containing the sodium fluoride-dinitrophenol mixture showed results similar to those of the other two mixtures containing the phenol compound except that the fluoride did not modify the toxic effect of the dinitrophenol on the growth of the organisms

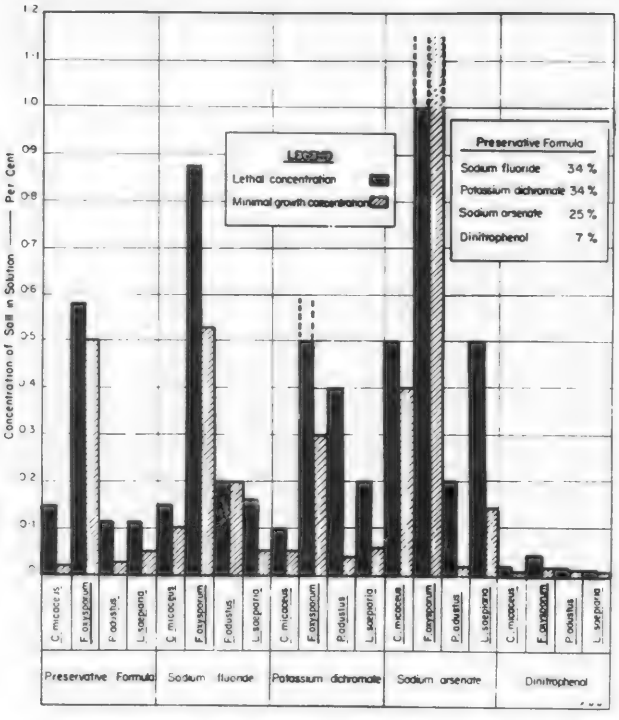

Fig. 1.—The lethal and minimal growth concentrations of the preservative mixture and its components on *C. micaceus, F. oxysporum, P. adustus,* and *L. saepiaria.*

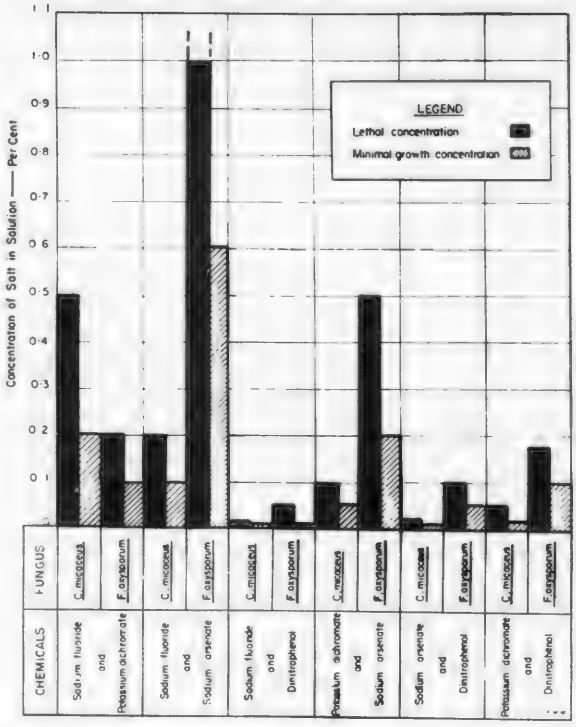

Fig. 2.—The lethal and minimal growth concentrations of various combinations of the preservative chemicals to *C. micaceus* and *F. oxysporum.*

to the same extent as the other mixtures. For *C. micaceus,* the minimal growth and lethal concentrations of the mixture were 0.005 and 0.01 percent, while corresponding figures for *F. oxysporum* were 0.02 and 0.05 percent, respectively.

A number of color mutants of *F. oxysporum* were observed, especially in cultures growing at the 0.04 and 0.05 percent concentrations of the complete preservative. Cultural characteristics of mutants that were isolated from sectors on the chemically treated plates remained constant over a period of 50 days and after at least two sub-cultures. Further culturing demonstrated reversions to the original type and the formation of new sectors in growing colonies.

Conclusions

A study of the results obtained (Figs. 1 and 2) shows that *Fusarium oxysporum* was easily the fungus most tolerant of all the chemical treatments except the sodium fluoride and potassium dichromate mixture. It was also the most tolerant of the complete preservative, while the *C. micaceus* was the least tolerant.

In most cases, it was found that the lethal and inhibitory concentrations of a mixture depended on the lethal and inhibitory concentrations of the most toxic individual component of the mixture. There were, however, a few cases when the antagonistic action of one compound was diminished by the complementary action of another. For instance, under the conditions of the experiments, both sodium arsenate and potassium dichromate reduced the toxicity of dinitrophenol to *C. micaceus* and *F. oxysporum* (Fig. 2). The sodium fluoride and dinitrophenol mixture was found to be much more effective against *C. micaceus* and the *Fusarium* than any other combination, including the preservative complex. Dinitrophenol proved to be the most potent fungistatic and fungicidal chemical. The *Fusarium* was comparatively tolerant of this compound, while both *P. adustus* and *L. saepiaria* grew more actively in the presence of this chemical than did the *Coprinus.* The phenol compound exerted its full individual preservative effect in the complex and in combination with sodium fluoride. Sodium arsenate was the least effective individual component in the series.

It was found that the temperature and humidity of the incubation room, which were higher and more uniform than those at ordinary room conditions, reduced the toxic effects of the chemical treatments to the fungi. For example, *C. micaceus* did not initiate growth at 0.15 percent concentration of sodium fluoride under room conditions, but this organism grew at the 0.18 percent concentration of the salt in the incubation room, which was maintained at 80° F. and 70 percent relative humidity.

When *F. oxysporum* grew on chemically treated media, especially at the higher concentrations close to the inhibition point, there was always an initial period of no growth or very little growth which preceded a period of much more active mycelial proliferation. This "lag period" of growth, together with the comparatively high tolerance of this organism to the test chemicals, and the observed readiness of the organism to change its cultural characteristics, seem to indicate that this fungus has an extensive enzyme system, both active and latent.

Because of the apparent invariable association of *C. micaceus* and *F. oxysporum* in treated fence posts, and since the former organism was much less tolerant of the treatments, it is suggested that the *Fusarium,* an abiquitous soil saprophyte, probably entered the treated posts and in some way reduced the toxicity of the wood preservative so that the entry and spread of the wood-decaying *C. micaceus* was facilitated. Thus, it is thought that decay of the treated posts was brought about by the complementary action of these two organisms.

Further investigations are being undertaken to study the possible metabolic detoxication of these chemicals by *F. oxysporum.*

BRUSH, DIP, AND SOAK TREATMENTS WITH

Water-Repellent Preservatives[1]

A. F. VERRALL
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Results of 18 years of testing show that surface treatments give worthwhile protection to porches, siding, and other exterior woodwork, but the treatments must be supplemented with adequate structural design.

PORCHES, STEPS, SIDING, FASCIA BOARDS, and other exterior woodwork are often exposed to decay hazard created by rain seepage. The hazard can be lessened by designing buildings so as to minimize wetting, but treatment is frequently desirable for added protection. The present investigations were started to determine the effectiveness and limitations of on-the-job application of preservatives. Particular attention was given to water-repellent preservatives, for wood impregnated with these is not generally available. Water repellents are as important as preservatives in treating exterior woodwork, because wetting, even without decay, leads to paint failures, warping, and nail pulling.

The test units were installed in southern Mississippi starting in 1941. The results, therefore, are based on exposures up to 18 years under conditions as severe as any in the United States.

Preliminary results were summarized in two earlier publications (2, 3).

Materials and Methods

Exposures included 2,400 units of various designs. In addition, approximately 6,000 units were exposed to obtain supplementary information on penetration and absorption of treating solutions (5, 6), water repellency (4, 6, 7), and decay protection under special conditions (6, 7).

The Author: Dr. Arthur Verrall holds degrees from the University of Minnesota. A pathologist, he has contributed numerous papers to the *Journal* on fungus deterioration of wood and its control.

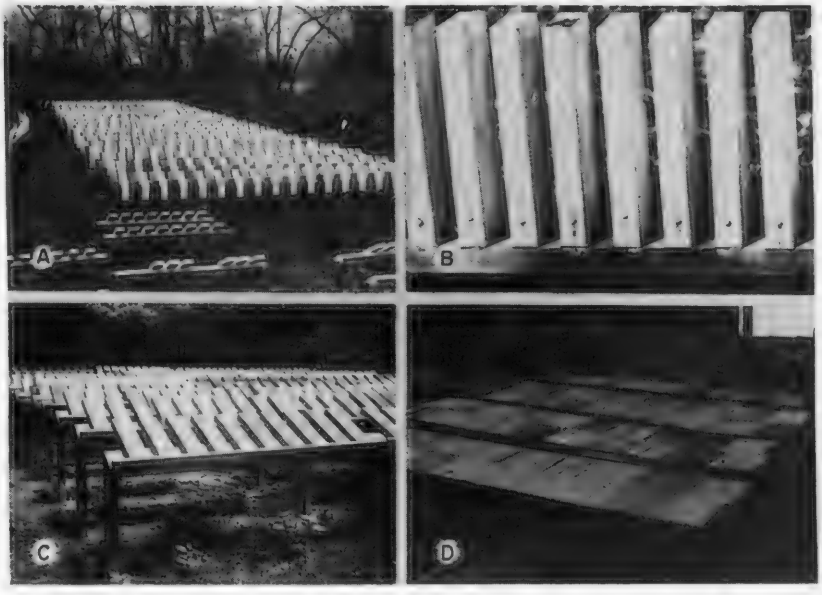

Fig. 1.—Experimental units and methods of exposure. (A) Simulated joint of step rail to newel, (B) columns, (C) a unit used to compare large numbers of treatments, and (D) flooring panels.

The investigations are based on the following four types of exposure units.

Step rail: A diagonal 10- to 12-inch 2 x 4 rail nailed to the side of a 12-inch 2 x 4 newel post (Fig. 1A). Rainwater runs down the top of the rail and penetrates the joint, creating a very high decay hazard.

Column: A 13-inch 2 x 4 toenailed to the top of a 2 x 4 sill. Decay hazard at the base of the column is high even though the sill is pressure-treated (Fig. 1B).

Weathering unit: A 12-inch length of 2 x 4 nailed flat to a 2 x 6 sill of similar treatment (Fig. 1C).

Demonstration units: Steps made of 2 x 10 carriages and treads and 1-inch risers; 2 x 2-foot porch flooring units fully exposed (Fig. 1D); 4 x 8-foot flooring units exposed under a roof edge; and window shutters made of 1 x 6 tongue-and-groove panels and 1 x 4 rails (Fig. 2D).

The step-rail joint seemed the most satisfactory test unit, because it offered a high decay hazard, and was easy to construct and administer. The column tended to work loose from the sill. In the weathering units, where several replicates were nailed to a common sill, serious decay in one joint interfered with maintenance of the rest of the set.

All lumber was southern pine. In most cases, the wood was matched among treatments; that is, one or two units from each piece of lumber were included in each test category. In one test where the number of categories prevented strict matching, the pieces were partly randomized. These procedures tended to reduce the variability among treatments. Most test categories had 20 to 25 samples; none had less than 10.

Most test units were given two coats of a titanium-lead-zinc paint and repainted at approximately 5-year intervals.

Treatment was by immersion or two brush applications at air temperatures, after the pieces had been cut to size but prior to assembly.

The units were exposed off the ground on pressure-treated sills but subject to rain seepage. The main exposure area was under partial hardwood shade, but some units were under an open longleaf pine stand.

Decay ratings were made annually on the following scale:

0. None obvious.
20. Discolorations but no obvious decay.
40. Obvious decay but limited to a small area.
60. Decay general but units still serviceable.

[1] A contributed paper received June 15, 1960; approved for publication Nov. 18, 1960.

Fig. 2.—Typical units after various exposure periods: (A) Flooring after 5.5 years. Left 7 boards received 3-minute dip in pentachlorophenol plus water repellent; next 3 boards were untreated; next 7 were given a 3-minute dip of end 7 inches only; (B) Flooring after 6.5 years. An essentially sound panel that received 3-minute dip in 5 percent pentachlorophenol plus a water repellent, and an untreated panel; (C) Columns after 8.5 years. From left to right in the respective groups: 30-minute soak in 0.2 percent phenyl mercuric oleate; untreated; and 30-minute soak in 5 percent pentachlorophenol; and (D) Window shutters after 18.5 years. Untreated shutter badly decayed, one given 30-minute soak in 5 percent pentachlorophenol is sound.

80. Advanced decay—unit would be replaced prior to normal repainting.
100. Complete failure.

In several cases average service life was determined after all units had failed; that is, reached a rating of 80. For both treated and untreated wood, these true averages corresponded closely to the point where a curve of percentage of failure over age intersected the 60 percent line. Therefore, average service life was determined by plotting the data to determine the age at which 60 percent had failed or would fail. With a single exception, no determination was made unless at least 50 percent failure had occurred. Rail units were considered to have failed when either rail or post rated 80. This accounts for some discrepancy between the average service life listed in Table 1 and in previous reports (3). For steps, flooring, and shutters each board was considered a separate unit.

Results and Discussion

Information on treatments, absorptions, exposure periods, wood conditions when treated, and current amounts of decay (as decay rating, percentage of failure, or service life) are given in Tables 1, 2, and 3. Some typical results are shown in Figure 2.

The most common fruiting bodies on both treated and untreated wood were *Lenzites saepiaria* and *Daedalea berkeleyi*. *Schizophyllum commune* and a yellow jelly fungus (presumably Dacromycetales) occurred occasionally.

The untreated southern pine sapwood units had an average service life of 3.0 years for unpainted rail units and 4.0 to 5.8 for painted rail units; 8.2 years for unpainted columns and 8.9 to 10.6 for painted columns; 4.5 years for unpainted steps and 2.9 to 7.2 years for painted steps, shutters, and flooring. In the one test where it was included, southern pine heartwood had an average life of 6.4 years when painted and 7.0 years when unpainted, as compared to 7.2 and 4.0 years for sapwood units. Because pine sapwood has no appreciable resistance to decay it is assumed that the differences in service life are due to variations in relative hazard of different types of units, variations in exposure conditions during different periods, the presence of undetected molds which increase absorptiveness and possibly inhibit decay, or incipient decay present when the wood was treated.

The service lives reported here are for severe exposure and not for exterior woodwork in buildings so designed as to remove the worst seepage hazards. Conversely, any benefits shown by the treatments should be conservative for treated wood used in a properly designed building.

In each case, preservative treatment increased service life but the degree of benefit varied with preservative, method of treatment, type of oil carrier, presence or absence of a water repellent, and whether or not the wood was painted. Under the conditions of these exposures, phenyl mercuric oleate was ineffective even at the high concentration of 0.35 percent and retentions of 3.7 pounds per cubic foot. Five percent zinc chloride failed even on the painted units.

These data and others based on many additional preservatives (6) indicate that, when all factors are considered, the preservatives covered by Federal Specification TT–W–572 pentachlorophenol and copper naphthenate) are equal or superior to the others tested for protecting wood by surface applications. Here, as in box protection studies reported earlier (6), tetrachlorophenol was approximately equal to pentachlorophenol in effectiveness. It seems worthy of more consideration for use in surface treatments.

The present data plus those from the box studies show that copper naphthenate at 1 to 2 percent Cu (metallic copper) is effective. When the copper content was dropped to 0.5 percent, failure occurred. Thus, in rail

Table 3.—RELATIVE EFFECTIVENESS OF TREATMENTS FOR WHICH AVERAGE SERVICE LIFE HAS BEEN DETERMINED

		Relative service life[1]
Unpainted sapwood		
Untreated		1.0
Copper naphthenate (0.5% Cu) in kerosene	5-sec. dip	1.1
do.	3-min. dip	1.2
0.35% phenyl mercuric oleate in kerosene	5-sec. dip	1.3
Creosote	3-min. dip	1.5
do.	5-sec. dip	1.6
0.35% phenyl mercuric oleate in kerosene	3-min. dip	1.6
5% pentachlorophenol in kerosene	5-sec. dip	1.7
Copper naphthenate (2% Cu) in kerosene	5-sec. dip	1.8
5% tetrachlorophenol in kerosene	5-sec. dip	1.9
10% pentachlorophenol in kerosene	5-sec. dip	1.9
5% pentachlorophenol in mineral spirits	3-min. dip	1.9
Copper naphthenate (2% Cu) in kerosene	3-min, dip	2.0
5% zinc chloride in water	3-min. dip	2.1
5% pentachlorophenol in kerosene	3-min. dip	2.7
5% tetrachlorophenol in kerosene	3-min. dip	2.7
0.35% phenyl mercuric oleate in kerosene	3.67 lbs./cu. ft.	2.8
5% pentachlorophenol + WR in mineral spirits	5-sec. dip	3.2
Copper naphthenate (0.5% Cu) in kerosene	4.08 lbs./cu. ft.	3.3
Painted sapwood		
5% zinc chloride in water	3-min. dip	1.3
0.2% phenyl mercuric oleate in kerosene	30-min. soak	1.8
Copper naphthenate (0.5% Cu) in kerosene	3-min. dip	1.8

[1]The values are not years but service life relative to that of comparable untreated units, which varied from test to test. Thus the treated wood lasted 1.1 to 3.3 times as long as the untreated.

Table 1.—EFFECTIVENESS OF BRUSH, DIP, AND SOAK TREATMENTS WITH OIL-CARRIED PRESERVATIVES IN PREVENTING DECAY OF PINE SAPWOOD EXPOSED OFF THE GROUND BUT SUBJECT TO RAIN SEEPAGE AT JOINTS

Type of test, preservative, and length of exposure	Oil carrier	Treating method	Painted?	Condition of lumber when treated	Solution absorbed Lbs./cu. ft.	Average decay rating[1]	Proportion failed[2] Per cent	Average service life[3] Years
Rail Test 1. 18.2 years' exposure								
5% pentachlorophenol	Kerosene	15-min. soak	yes	kiln-dried, bright	1.52	0	0	----
do.	do.	30-min. soak	yes		1.57	0	0	----
do.	do.	60-min. soak	yes		1.79	0	0	----
Untreated	----	----	yes		----	100	100	5.3
Rail Test 2. 17.4 years' exposure								
5% pentachlorophenol	Kerosene	30-min. soak	yes	air-dried, 5% stain	[4]	0	0	----
do.	do.	2 brush coats	yes			31	33	----
Copper naphthenate, 0.5% Cu	do.	30-min. soak	yes			32	25	----
do. , 2.0% Cu	do.	2 brush coats	yes			38	44	----
Non-toxic end coating	----	brush coat	yes			88	80	9.5
Untreated	----	----	yes			100	100	5.8
do.	----	----	no			100	100	3.0
Rail Test 3. 12.9 years' exposure								
5% pentachlorophenol	Min. spirits	3-min. dip	yes	partially kiln-dried	[4]	0	0	----
do.	do.	end dip + side brush	yes	6% stain		16	25	----
5% pentachlorophenol + WR	do.	3-min. dip	yes			12	20	----
do.	do.	end dip + side brush	yes			16	25	----
Untreated	----	----	yes			97	100	4.0
Column Test 1. 18.0 years' exposure								H
5% pentachlorophenol	Kerosene	30-min. soak	yes	air-dried, 8% stain	[4]	52	0	----
5% pentachlorophenol + WR	Min. spirits	do.	yes			54	0	----
Untreated	----	----	yes			100	100	10.6
do.	----	----	no			100	100	8.2
Column Test 2. 17.7 years' exposure								
5% pentachlorophenol	Kerosene	30-min. soak	yes	probably kiln-dried	1.49	46	0	----
0.2% phenyl mercuric oleate	do.	do.	yes	bright	1.25	70	67	16.4
Untreated	----	----	yes		----	100	100	8.9
Shutter Test. 18.2 years' exposure								
5% pentachlorophenol	Kerosene	30-min. soak	yes	kiln-dried, bright	2.30	0	0	----
do.	do.	60-min. soak	yes		2.54	0	0	----
Untreated	----	----	yes		----	94	96	7.0
Flooring Test 1. 11.8 years' exposure								
5% pentachlorophenol	Min. spirits	3-min. dip	yes	kiln-dried	1.48	44	0	----
do.	do.	do.	no		----	62	14	----
5% pentachlorophenol + WR	do.	do.	yes	trace of stain	.88	42	7	----
do.	do.	do.	no		----	66	28	----
Untreated, loaded joints	----	----	yes		----	100	100	6.2
Untreated, plain joints	----	----	yes		----	100	100	3.1
Flooring Test 2. 11.8 years' exposure								
5% pentachlorophenol	Min. spirits	3-min. full-length dip	yes	air- and kiln-dried	2.30	50	21	----
do.	do.	3-min. end dip	yes	kiln-dried	----	100	100	6.0
5% pentachlorophenol + WR	do.	3-min. full-length dip	yes	8% stain	1.51	64	28	----
do.	do.	3-min. end dip	yes		----	100	100	3.7
Untreated, loaded joints	----	----	yes		----	100	100	6.0
Untreated, plain joints	----	----	yes		----	100	100	2.9
Step Test. 12.9 years' exposure								
5% pentachlorophenol + WR	Min. spirits	3-min. dip	yes	Partially kiln-dried, no stain, but light mold[5]	[4]	44	21	----
Untreated	----	----	yes			100	100	4.0
do.	----	----	no			100	100	4.5

[1] On a basis of 0 (none) to 100 (destroyed).
[2] Proportion of samples with decay ratings of 80 or above.
[3] Time required for 60 per cent of the samples to fail.
[4] Not determined.
[5] Lumber was wetted by rain in transit and molded during redrying.

Table 2.—EFFECTIVENESS OF DIP AND SOAK PRESERVATIVE TREATMENTS ON SOUTHERN PINE SAPWOOD AND HEARTWOOD AFTER 12.3 YEARS' EXPOSURE OFF THE GROUND BUT SUBJECT TO RAIN SEEPAGE[1]

Chemical, concentration, and type of wood	Solvent	Solution absorbed			Decay rating[2]						Average service life[3]					
					Unpainted			Painted			Unpainted			Painted		
		5-sec. dip	3-min. dip	Soak	5-sec. dip	3-min. dip	Soak	5-sec. dip	3-min. dip	Soak	5-sec. dip	3-min. dip	Soak	5-sec. dip	3-min. dip	Soak
		Lbs. cu. ft.									Years					
Sapwood																
5% pentachlorophenol	Kerosene	0.7	1.2	4.2	100	100	30	36	0	0	6.7	11.0	(0)	(21)	(0)	(0)
10% do.	do.	.7	1.2	4.7	100	70	30	---	---	---	7.5	(25)	(0)	----	---	---
5% pentachlorophenol + WR	do.	.7	1.2	4.7	78	64	36	---	---	---	12.6	(25)	(0)	---	---	---
5% tetrachlorophenol	do.	.9	1.2	3.9	100	98	46	52	0	0	7.5	10.7	(0)	(33)	(0)	(0)
Coal-tar creosote	None	1.1	1.4	5.7	100	100	24	---	---	---	6.2	6.1	(0)	----	---	---
.35% phenyl mercuric oleate	Kerosene	.7	1.1	3.7	100	100	94	---	---	---	5.1	6.5	11.3	---	---	---
Copper naphthenate, 0.5% Cu	do.	.8	1.1	4.1	100	100	84	44	70	0	4.5	4.6	13.0	(10)	13.0	(0)
do. , 2% Cu	do.	.7	1.1	6.4	100	100	10	---	---	---	7.3	8.0	(0)	----	---	---
5% zinc chloride	Water	---	1.2	---	---	86	---	---	100	---	---	8.2	---	---	9.2	---
Untreated	None	---	---	---	100	---	---	100	---	---	4.0	---	---	7.2	---	---
5% pentachlorophenol	Mineral spirits	---	1.4	---	---	100	---	---	---	---	---	7.8	---	---	---	---
do.	Kerosene	---	1.2	---	---	100	---	---	---	---	---	11.0	---	---	---	---
do.	No. 2 fuel oil	---	1.2	---	---	76	---	---	---	---	----	(42)	---	---	---	---
Heartwood																
5% pentachlorophenol	Kerosene	---	.7	---	---	66	---	---	0	---	---	(33)	---	---	(0)	---
Creosote	None	---	1.0	---	---	80	---	---	---	---	---	13.0	---	---	---	---
Copper naphthenate, 0.5% Cu	Kerosene	---	.5	---	---	82	---	---	30	---	---	12.4	---	---	(17)	---
Untreated	None	---	---	---	---	100	---	---	100	---	---	7.0	---	---	6.4	---

[1] The weathering unit used is shown in Figure 1C.
[2] On a basis of 0 (none) to 100 (destroyed).
[3] Time required for 60 percent of the samples to fail (i. e., have decay ratings of 80 or more). The figures in parentheses indicate percent of failures for the better treatments for which average service life has not been determined.

test No. 2, a brush treatment with 2 percent Cu outperformed a 30-minute soak in 0.5 percent Cu. The 0.5 percent Cu at 4.1 pounds per cubic foot also failed in the exposures summarized in Table 2.

In general, the 5-second dip did not double the service life of unpainted units unless a water repellent was included. Painting considerably extended the life of wood given a 5-second dip or brush application. From the amount of decay evident after 12.3 to 12.9 years, however, the point of average service life is probably near. The 3-minute dip was somewhat more effective but not sufficiently so to warrant its use on wood to be left unpainted. On subsequently painted units, the 3-minute dip allowed appreciable decay, but still gave worthwhile protection. During 11.8 to 12.9 years' exposure of samples painted after being given 3-minute dips, the percentages of failure in different tests were 0, 20, 0, 7, 21, 28, 0, and 0 (excluding the ineffective copper naphthenate at 0.5 percent Cu).

The 15-, 30-, and 60-minute soaks and the long-time soak to give retentions of 4 to 6 pounds per cubic foot have given excellent protection for at least 12.3 to 18.2 years. The long-time soak was reasonably effective, even with unpainted units (Table 2). Some decay in and failure of soaked units has occurred but there is little doubt that soaks would give long-time protection for the wood in buildings designed to prevent most rain seepage.

The heavier the oil carrier the greater was the protection afforded by a 3-minute dip in 5 percent pentachlorophenol (Table 2). The average service lives for the samples treated in mineral spirits, kerosene, and a No. 2 fuel oil were 7.8, 11.0, and 14.1 years, respectively. Similar results have been reported for pressure treatments (1). The differences may not be due to weight of oil per se, but to such associated factors as rate of evaporation or aromatic content. If the treated wood is to be left unpainted a carrier at least as heavy as a No. 2 fuel oil seems desirable for dip treatments. Where paintability is a factor, the lighter mineral spirits solutions are best because they reduce the danger of bleeding through the paint.

Water repellents are known to decrease both absorption and penetration of treating solutions (5, 6). The addition of water repellents likewise decreased absorptions in the current trials (Tables 1 and 2). Nevertheless, the solutions of pentachlorophenol plus a water repellent were as effective as—or more effective than—similar solutions without the water repellent. Other data clearly showed that water repellents slow rain entry into siding under severe exposure conditions (4). There is no doubt that a water repellent is desirable in all treatments for exterior woodwork that is to be painted.

Oil paint had no consistent effect on untreated units, but markedly increased the effectiveness of 5-second and 3-minute dips and to some extent even the long-time soaks (Tables 1 and 2). Extensive additional data from other trials corroborate these results (6). Presumably, the salutary effect of paint is mainly in reducing the amount of surface checking which might expose untreated interiors and possibly in decreasing loss of toxicants through volatilization. Whatever the reason, surface-treated wood-work needs the protection of an oil paint.

The data here are for southern pine only. Another rail test, established in southern Mississippi in 1952, includes four of the West Coast woods commonly used in building construction, as well as southern pine. So far there is no difference among species in the effectiveness of a 3-minute dip in 5 percent pentachlorophenol plus a water repellent. In the box exposures previously reported (6), the same treatment gave approximately equal protection to most of the 8 wood species tried. A notable exception was the high degree of protection given Douglas-fir heartwood. Treated wood of this species showed practically no decay after 4.4 years' exposure, while the untreated wood had failed completely.

A non-toxic end coating was used in the joints of rail units in Rail Test No. 2 (Table 1) to reduce rain seepage. The average service life was only 1.5 times that of untreated units. Caulking floor joints with white lead —a standard practice a few years ago —doubled service life in each of two trials (Table 1). In other studies, end plus back painting of siding (but not end painting alone) greatly reduced decay hazard in siding fully exposed to rainwetting (4, 7), and water repellents without a toxicant somewhat reduced decay rate in exposed boxes (6). Even though caulking, joint sealers, and repellents reduce decay by partially excluding water, it seems advisable also to use a toxicant on decay-susceptible wood exposed to an appreciable decay hazard.

Conclusions

The exposure trials reported here and elsewhere (4, 6, 7) show that preservatives applied by brushing, dipping, or soaking have legitimate uses in wood protection, particularly if a water repellent is included. Penetration of the preservative is restricted, in brush and dip treatments, however, and long-time protection can be expected only in structures designed to prevent frequent and severe wetting and to promote rapid drying after wetting (8).

For parts of buildings where wood is likely to remain wet for protracted periods, it is safest to use either heartwood of a naturally decay-resistant species or wood adequately impregnated with a preservative (according to Federal Specification TT–W–571 or the standards of the American Wood Preservers' Association). This statement applies to any wood in contact with the soil or moist concrete; exposed steps and porches in high rainfall areas; any wood in showers, cold-storage rooms, low unventilated crawl spaces, or other places where condensation or seepage is frequent. In regions of high rainfall, it applies even to siding, fascia, and other exterior woodwork if unprotected by roof overhang. However, these investigations show that cold soaks of 30 minutes or longer will afford good protection to wood exposed off the ground but subject to a high decay hazard from rain seepage.

For on-the-job applications, water-repellent preservatives should meet Federal Specification TT–W–572 or the Standards of the National Woodworkers' Association. Because only a surface treatment results from simple applications, the wood must be cut to size and shape before treatment, and any subsequently cut surfaces must be retreated.

Literature Cited

1. Blew, J. O. 1958. Comparison of wood preservatives in stake tests. U. S. For. Serv., For. Prod. Lab. Rept. 1761. 50 pp., illus.
2. Verrall, A. F. 1946. Preservative treatments for use on wood off the ground. Agric. Eng. 27: 367–368, 370, illus.
3. ———— 1953. Decay prevention in wooden steps and porches through proper design and protective treatments. Jour. For. Prod. Res. Soc. 3(4): 54–60. illus.
4. ———— 1953. Factors leading to possible decay in wood siding in the south. U. S. Dept. Agr. For. Path. Special Release 39. 17 pp., illus.
5. ———— 1957. Absorption and penetration of preservatives applied to southern pine wood by dips or short-period soaks. U. S. For. Serv. South. For. Expt. Sta. Occas. Paper 157. 31 pp.
6. ———— 1959. Preservative-moisture repellent treatments for wooden packing boxes. For. Prod. Jour. 9(1): 3–24. illus.
7. ———— 1960. Preventing moisture problems in wood siding in the south. For. Prod. Jour. 10(3): 148–151. illus.
8. ———— 1959. Control of wood decay in buildings. Pest Control Magazine 10(27): 9, 11–13, 16, 18, 71–72, 74, illus.

SOME FACTORS AFFECTING

Resin Efficiency in Flake Board[1]

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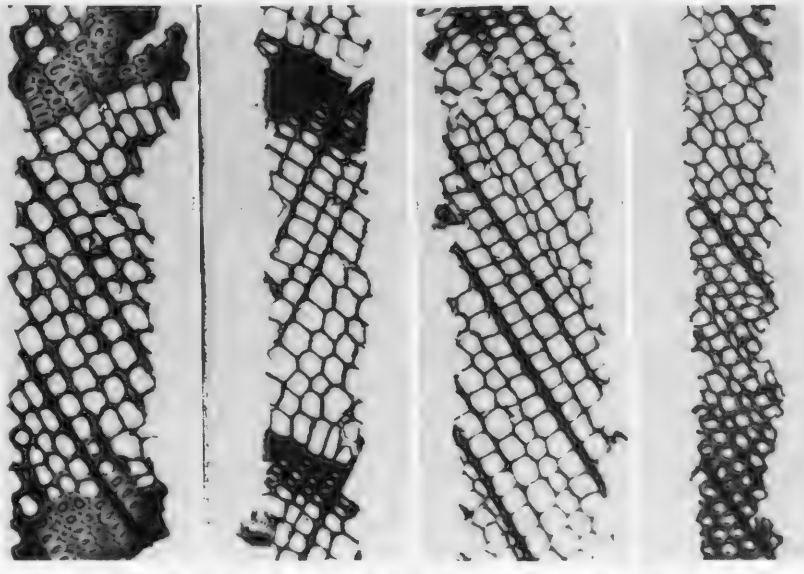

Fig. 1.—Microscopic cross sections of flakes, from left to right: slow growth flaked at high moisture content; slow growth flaked at low moisture content; fast growth flaked at high moisture content; fast growth flaked at low moisture content.

IMPORTANCE OF EFFICIENCY in resin application as it applies to manufacture of particle board cannot be over-emphasized. This statement is obvious, as cost of synthetic resins ranges from 30 to 60 percent of total manufacturing cost. The question of how to obtain maximum efficiency from this expensive raw material naturally has been of considerable interest.

Application of a minimum quantity of adhesive to wood particles, with resulting optimum physical properties in a pressed board, would be a suitable definition for resin efficiency. Achieving this goal is not so simple as the definition might suggest. There are many factors that determine extent of resin efficiency, from characteristics of the raw materials—that is, wood particles, resin and other additives—to the manufacturing process itself.

Lack of basic information has prevented thorough understanding of elements that affect efficiency of resin. Undoubtedly, one reason for this deficiency can be attributed to difficulty in studying the subject. For illustration, one might attempt to answer the question of how to measure, quantitatively or qualitatively, efficiency of resin distribution on wood particles.

Necessity of academic and also practical information is apparent; several prominent researchers on particle board have voiced this view. Dr. Wilhelm Klauditz (7)[2] states: "Exact examination of the gluing processes of wood chips in the production of wood chipboards is considered as very purposeful and necessary." Dr. George Kitazawa (6) says: "It is highly desirable that the industry understand the mechanisms operating in the durability of boards, primarily mechanisms relating to inter-particle adhesion."

Resin coverage on flakes, atomization, and inter-particle adhesion were investigated. Flake-to-flake bonding appeared to be adequate, but some resin evidently was functioning inefficiently.

Objective of the study reported here was to investigate several factors suspected of influencing resin efficiency. Extensive observations were made on the wood particles (flakes), atomization of the synthetic binder (phenol-formaldehyde resin), and glue bond in the pressed board.

Flakes were selected for study because their dimensions could be controlled and their surfaces could be studied easily. Phenolformaldehyde resin was chosen because, when cured, this adhesive is dark and can be seen plainly.

Flakeboards were tested, and data on modulus of rupture and internal bond were analyzed statistically to evaluate effects of moisture content at time of flaking, degree of resin atomization, and resin content.

Work by Others

"Engineered" particles or flakes have been developed because of emphasis on high quality. Researchers such as Marian (13), Kollman (9), Marra (14), and Klauditz (8) have proclaimed the significance of proper preparation of particles and have suggested a relationship with resin efficiency. Moisture content at time particles are produced is important to chip quality, as noted by Lynam (12). Herdey (5) cites histological structure of wood raw material as being important to quantity and type of binder.

Significance of the process for resin application is mentioned in several references. Hadley (4) and Kollman (10) advocate covering wood particles with a micro-thin layer of resin, but also realize the impracticality of this. Fehn (3) emphasizes that resin should remain on particle surfaces and not penetrate. Marra (15) points out the ultimate goal in resin application as deposition of an equal quantity of binder on each wood particle in such a manner as to insure even distribution of resin on particle surfaces. Several workers, among them Marian (13) and Kollman (11), discuss atomization and suggest its importance to proper application of resin. Brumbaugh (1) has studied the influence of size of resin droplets, and has shown that physical properties of flakeboards change when droplet size

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[1] A 1960 Wood Award entry, taken from a thesis submitted for the MS degree at Oregon State College.

[2] Numbers in parentheses refer to the Literature Cited at the end of this paper.

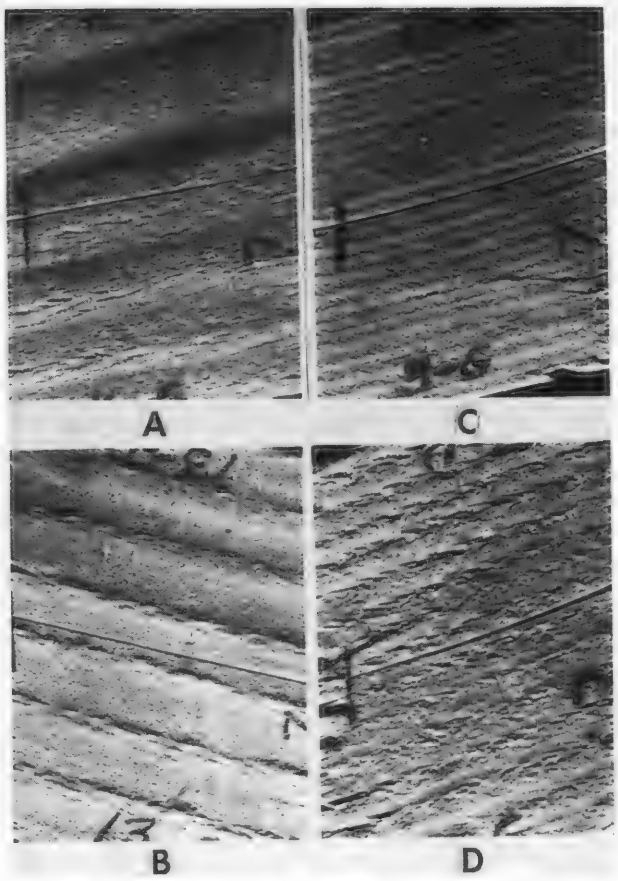

Fig. 2.—Flakes cut from blocks at low moisture content (26 percent). Highlighting shows variety of surface profiles: A, fast growth, smooth surface; B, fast growth, rough surface; C, slow growth, smooth surface; D, slow growth, rough surface. Bottom halves of flakes are undried; top halves are dried.

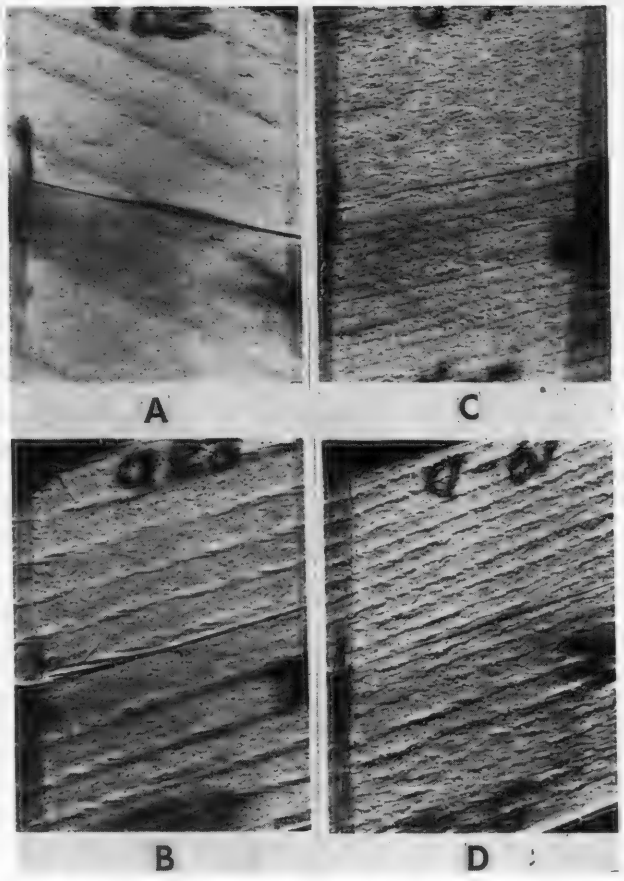

Fig. 3.—Flakes cut from blocks with high moisture content (116 percent). Highlighting shows variety of surface profiles: A, fast growth, smooth surface; B, fast growth, rough surface; C, slow growth, smooth surface; D, slow growth, rough surface. Bottom halves of flakes are undried; top halves are dried.

is varied. The objective of a study by Suchsland (17) was to produce, test, and evaluate the quality of glue bonds similar to those occurring in the manufacture of flakeboard. Under carefully controlled conditions for spraying, he illustrated that, with low-density woods, glue spreads as low as 0.3 gram to a square foot produced bonds with shear strengths higher than that of the wood.

Experimental Procedure

One- by 4-inch unseasoned boards of Douglas-fir were obtained from a local sawmill. The boards were flat-grained, mostly sapwood, and averaged 12 rings to an inch. Boards were cut into blocks 4 inches square that were separated randomly into two groups. One group was stored at conditions for 20 percent equilibrium moisture content (90° F temperature and 90 percent relative humidity). Remaining blocks were immersed in water and stored at 35° F. After conditioning for two months, blocks immersed in water averaged 116 percent moisture content; other blocks averaged 26 percent.

Blocks were reduced to flakes in a disc-type flaker at the laboratory of Washington State Institute of Technology, Pullman, Washington. Flakes, cut from the radial edge of blocks, measured a maximum of 1 inch in length and width; they averaged 0.015 inch in thickness. Precautions were taken to assure that knives were consistently sharp, especially when blocks of low moisture content were being sliced. Flakes were kept separate according to moisture content at flaking.

Drying was accomplished at room conditions. After two months of air drying, moisture content of the flakes had stabilized at about 9 percent.

Dried flakes were screened on an oscillating chip screen. Only flakes retained on a 2-mesh screen were considered acceptable. Yield of acceptable flakes cut at high moisture content was 56 per cent and for flakes cut at low moisture content, 53 per cent. Differences here were judged insignificant.

Both groups of screened flakes were divided in half to form four sub-groups. Two of these sub-groups, each representing a different moisture content at time of flaking, were air-dried further from 9 percent to 6 percent at 90° F and 22 percent relative humidity. Drying was accomplished in one month. Purpose of drying flakes to two levels of moisture content was to assure a like moisture content for all mats. With two levels of resin content (2 percent and 6 percent), flakes at 6 percent moisture content were to be sprayed with 6 percent resin, and flakes at 9 percent moisture content were to be sprayed with 2 percent resin. Moisture content of flakes and resin content were, thus, so arranged as to achieve uniformity in moisture content for the mats.

Observing Flake Characteristics: An investigation of flakes was made under the microscope. Internal and external structure was observed and evaluated qualitatively according to moisture content at time of flaking, rate of growth and, in some instances, effects of drying.

Microscopic cross sections of flakes were prepared to study degree of internal damage. Unseasoned flakes were softened, then sectioned on a microtome. Flakes with fast and slow

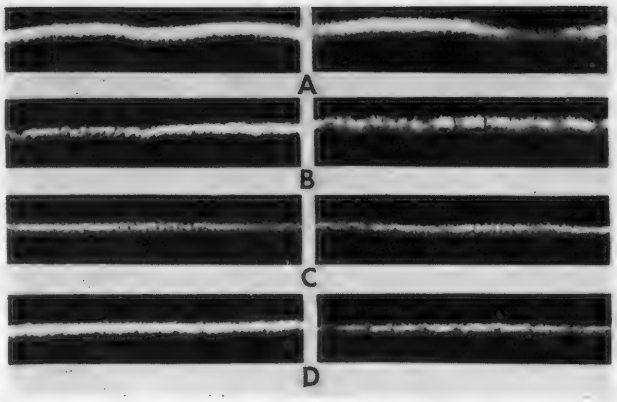

Fig. 4.—Light sections of flake surfaces: A, fast growth flaked at high moisture content; B, slow growth flaked at high moisture content; C, fast growth flaked at low moisture content; D, slow growth flaked at low moisture content. Sections on right were photographed in undried conditions; sections on left are same flakes after drying.

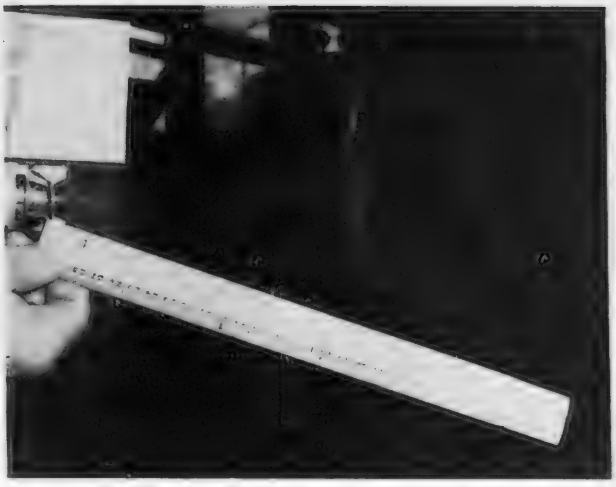

Fig. 5.—Observing resin spray in mid-air.

growth (more or less than 6 rings to an inch) and two moisture contents at time of flaking are shown in Fig. 1. Sections were selected to portray several findings made during microscopic observations.

Internal damage was negligible in all flakes, regardless of rate of growth or moisture content when they were made. In a few flakes, rupture in the summerwood occurred (Fig. 1, A and B). Surface damage was apparent, but could not be correlated with moisture content at time of flaking, or rate of growth. Injury at the surface generally was restricted to the outermost row of cells, although sometimes it extended into the second row of cells.

Flake surfaces were investigated in several ways. One method, "highlighting", described by Elmendorf and Vaughan (2), was used to observe the entire flake surface. By positioning a light source at an angle to the flake, ridges and depressions on the surface were differentiated. Macrophotographs were taken of flakes in an effort to correlate smoothness or roughness with moisture content at time of flaking, rate of growth, and surface changes due to drying.

In Figs. 2 and 3, several flake surfaces are represented. In each photograph, the bottom half of the flake is undried, and the top half has been dried to 9 percent moisture content. Major differences in surface quality, due to the three conditions stated above, were anticipated, but were not found. In some instances, flakes cut at lowest moisture content had smoother surfaces than flakes cut at high moisture content, and vice versa. Also, rate of growth appeared to have no connection with surface quality. Contrary to expectations, drying had no obvious effect on profile. Probably, inherent variability of wood flakes was extensive enough to eliminate distinct difference between surfaces.

Another technique employed to observe flake surfaces has been called "light-sectioning". This process is described by Stumbo (16) and by Elmendorf and Vaughan (2), who call it the light-ribbon test. Procedure is to project a thin ribbon of light on an inclined surface and photograph the display. In this fashion, surface contours can be observed and evaluated. Macrophotographs were taken of flake-surface profiles with light projected across the grain. Several of these light-sections are shown in Fig. 4. Photographs are arranged in pairs to illustrate flakes in undried and dry conditions; flakes were photographed initially undried, then were dried and rephotographed in essentially the same location. Surface smoothness or roughness was difficult to relate to moisture content at time of flaking, or to effect of drying. Again, as related previously, variability of flakes was thought to be too great to discern distinct differences in surface quality. Two distinctions were noted relative to rate of growth, however. First, fast-growth flakes (fewer than 6 rings per inch) were nearly all characterized by sine curve profiles; flakes with slow growth did not show this contour (compare Fig. 4A and 4D). Secondly, surfaces of fast-growth flakes appeared to be smoother than those of slow-growth flakes (compare Fig. 4, C and B).

Preparing Panels: Flakes and resin were mixed in a batch-type mixer. No wax was added. Phenol-formaldehyde resin (Monsanto PF575) was sprayed, undiluted, at 70° F. Resin contents were either 2 or 6 percent, based on oven-dry weight of the flakes. Rate of resin emission was constant at 20 grams of resin solids per minute. Degree of atomization was varied from fine to coarse by changing atomizing air pressure from 80 to 60 pounds. After chips were blended, moisture contents averaged 10.8 percent.

Mats were 3 inches thick and measured 18 by 18 inches. Panels were pressed to ½-inch thickness with metal stops; press closing time averaged 2½ minutes. Initial pressing pressure was 250 pounds per square inch, pressing temperature was 330° F, and press cycle lasted 12 minutes. To assure complete resin cure, each board was sealed in a plastic sack immediately after it was pressed and placed in an oven at 150° F for 20 hours. Panels were cooled and trimmed into 15-inch squares preparatory to the cutting of test specimens. Twenty-four panels were prepared.

Resin Atomization, Distribution, and Bonding: To observe resin atomization, several techniques were tried. When viewed in mid-air (Fig. 5) degrees of atomization were distinct, after enlargement. Enlargements were made of the spray area 10 inches from the nozzle, the distance from gun to flakes during mixing. Fine atomization produced smaller droplets than coarse spray did.

To further establish differences in atomization, resin was sprayed onto paper, and the resin droplets were heat-cured to obtain a display. One method involved exposing the paper to a short blast of spray at a distance of 10 inches. A shield was placed between the gun and paper and lifted for a split-second exposure. Results are shown in Figs. 6F and 6C. By this technique, differences in degrees of atomization could be observed. When inspected closely, spray patterns of coarse atomization typically had more large droplets than did patterns of fine atomization.

Results of another technique to observe resin-spray patterns are shown in Figs. 7F and 7C. Here, the paper was dropped through the spray, thus simulating the condition that might

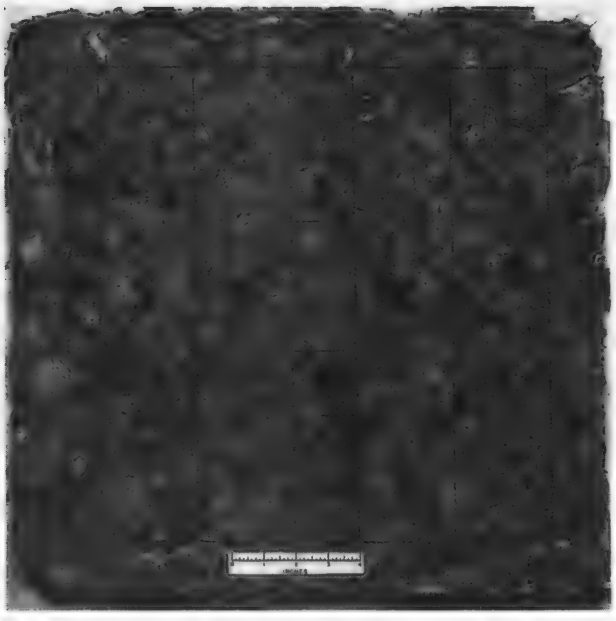

Fig. 10.—Manner in which test specimens were cut from 18-inch-square flakeboards. S, static bending; I, internal bond.

Table 1.—RESULTS OF PHYSICAL TESTS

Specimen[1]	Modulus of rupture[2] Psi	Internal bond[3] Psi	Moisture content at test[3] Percent	Specific gravity[4]
1LF2	3286	78	7.7	0.62
1LF6	2923	146	6.8	0.62
1HF2	3095	57	7.8	0.69
1HF6	3848	127	8.1	0.65
1LC2	2505	58	8.9	0.68
1LC6	2945	137	8.9	0.70
1HC2	2935	61	8.9	0.70
1HC6	4100	125	7.9	0.67
2LF2	2846	77	8.2	0.66
2LF6	3825	136	8.1	0.65
2HF2	2662	61	8.1	0.69
2HF6	3592	98	8.6	0.69
2LC2	3073	63	8.7	0.71
2LC6	3833	145	8.1	0.70
2HC2	2721	56	8.6	0.63
2HC6	3977	115	8.1	0.70
3LF2	2898	94	7.7	0.74
3LF6	3662	150	7.6	0.66
3HF2	2506	73	7.8	0.66
3HF6	4291	114	7.4	0.69
3LC2	2858	68	8.3	0.68
3LC6	3511	151	8.4	0.67
3HC2	2431	49	8.0	0.67
3HC6	4298	107	7.9	0.68

[1]Specimen coding:
First number indicates replication.
First letter indicates moisture content at flaking: L for low (26%), H for high (116%).
Second letter indicates degree of atomization: F for fine, C for coarse.
Second number indicates resin content: 2% and 6%.
[2]Averages based on 3 observations.
[3]Averages based on 2 observations.
[4]Averages of 2 observations, based on oven-dry weight and volume at time of test.

exist in mixing; that is, free-falling, tumbling flakes passing through the spray. Spray patterns did show differences, mainly in size of resin droplets and extent of coverage; fine spray had few large droplets and covered well.

Extensive observations were made of resin-coated flakes. On the basis of resin coverage, flakes sprayed with 2 percent resin were distinguished easily from those sprayed at 6 percent. Distinction between fine and coarse atomization was impossible when observing flakes sprayed with 6 percent resin. Atomization levels were also difficult to distinguish on basis of coverage and size of resin droplets at 2 percent resin content.

Macrophotographs of some resin-coated flakes are shown in Fig. 8. When resin-coated flakes were viewed under a binocular microscope, resin droplets were observed to vary in size and shape. Most droplets were on the flake surfaces, but some were found deeply embedded in surface cracks and fissures.

Some observations were made of inter-particle adhesion in the pressed panel. To do this, small pieces of board were split apart with a knife; cleaved sections then were examined. Some of these sections are illustrated in Fig. 9. In most instances, the resin apparently had performed a "spot-welding" function. There was evidence of efficient bonding—many areas showed considerable wood failure (Figs. 9C and 9D). Resin appeared as amorphous-like blotches in most instances. There were areas, however, where resin undoubtedly had not performed efficiently. In some areas, flake-to-flake contact had not been made. Resin in these locations appeared as droplets and not as blotches (Fig. 9A). In other areas, the resin apparently had been embedded in surface fissures and had not performed its bonding function; this resin appeared also as droplets (Fig. 9B).

Physical Tests: Specimens to measure static bending and internal bond were cut from each panel as shown in Fig. 10. Specimens were stored at conditions for 12 percent equilibrium moisture content (70°F and 65 percent relative humidity). After several weeks, they had equalized to an average moisture content of 8 percent and were ready for testing.

Modulus of rupture was measured in the static bending test. Specimens 3 by 14 inches in size were loaded at a rate of 0.24 inch per minute over a 12-inch span. Blocks were cut from these specimens after test to measure specific gravity; average for all specimens was 0.67.

Specimens to measure internal bond, 2 by 2 inches square, were tested at a head-speed of 0.04 inch per minute. Procedures for performing this test and the test for modulus of rupture are described in detail in Standard D 1037–56T, American Society for Testing Materials.

Results of physical tests are presented in Table 1.

Statistical Analysis

Data were analyzed with a split-plot, factorial design. Three factors, each with two levels, were investigated: moisture content at flaking (26 and 116 percent), resin content (2 and 6 percent), and degree of atomization (fine and coarse).

Mean values for modulus of rupture (MOR) and internal bond are presented in Table 2. Information presented in this table is general, and interpretation should *not* be made without considering the analysis of variance in Table 3. A discussion of significant information based on the analysis of variance follows. Bar graphs have been prepared to show significant interactions only; discussion of significant main effects has not been included since explanation of these effects is contained in the discussion on interactions.

For modulus of rupture, the interaction between moisture content at flaking and resin content (MXR) was significant (Fig. 11). At a resin content of 2 percent, higher MOR values occurred at the low (26 percent) moisture content. For 6 percent resin content, this situation was reversed. At either moisture content, boards with 2 percent resin content exhibited values for modulus of rupture lower than those of boards with 6 percent resin content.

Table 2.—FACTOR MEANS[1]

Factors	Physical properties: Modulus of rupture Psi	Physical properties: Internal bond Psi
Atomization		
fine	3286	101
coarse	3266	95
Moisture content at flaking		
26 percent	3181	109
116 percent	3371	87
Resin content		
2 percent	2818	66
6 percent	3734	129

[1]Each mean value was based on 36 observations for modulus of rupture and 24 observations for internal bond.

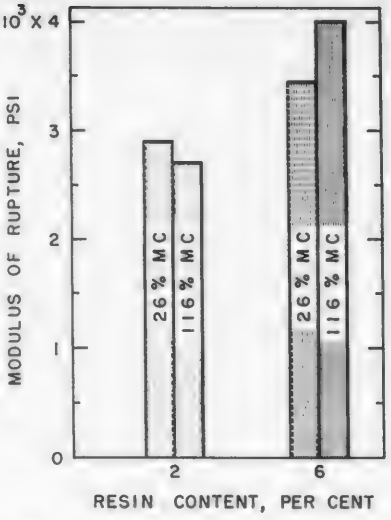

Fig. 11.—Interaction of resin content with moisture content at time of flaking. Each bar value represents a mean of 18 observations.

A significant interaction between resin content and moisture content at flaking for internal bond is shown in Fig. 12. Regardless of resin content, best internal-bond strengths were realized at the low moisture content. Also, at either moisture content, higher internal-bond values occurred with high resin content.

Interaction between resin content and degree of atomization for internal bond is portrayed in Fig. 13. This was the only instance where atomization appeared significant. At the lower resin content, fine atomization resulted in highest value for internal bond. At 6 percent resin content, however, coarse atomization showed a slight advantage in strength over fine atomization.

Conclusions

Observations and qualitative evaluations illustrated several interesting occurrences. These can be enumerated as follows:

1. Examination of cross sections of flakes showed negligible internal damage, irrespective of moisture content at time of flaking or rate of growth. Damage was restricted to flake surfaces and extended one cell, or sometimes two cell widths, inward.

2. Observations of flake surfaces by two techniques, high-lighting and light-sectioning, showed that no distinct differences in roughness of surface or in profile could be established according to moisture content at time of flaking or degree of flake dryness. With light-sectioning, however, a discernible difference was noticed for rate of growth. Regardless of moisture content, fast-growth flakes exhibited generally smoother surfaces than did slow-growth flakes. Selection of wood for flaking on the basis of growth rate

Table 3.—F VALUES IN ANALYSIS OF VARIANCE

Source of variation	Degrees of freedom	Physical properties: Modulus of rupture	Physical properties: Internal bond
Replications	2	0.51	0.80
Atomization (A)	1	0.04	1.94
Error (a)	2		
Moisture content (M)	1	1.66	43.12**
Resin content (R)	1	38.17**	364.57**
MXA	1	0.44	1.13
MXR	1	6.46*	6.13*
RXA	1	0.53	5.64*
MXAXR	1	0.04	0.50
Error (b)	12		

*Significant at 5 percent level.
**Significant at 1 percent level.

thus appears important to production of high-quality flakes.

3. Inspection of the glue bond in the pressed board showed a spot-weld adhesion between flakes. In most instances, resin appeared to be on the flake surfaces, and flake-to-flake bonding seemed adequate. There was evidence, however, that some of the resin was not doing any bonding. Such resin often was embedded in cracks and fissures on flake surfaces, thus emphasizing the importance of smooth-surfaced flakes.

Conclusions based on quantitative measurements of physical properties of the boards may be summarized as follows:

1. Both modulus of rupture and internal bond were sensitive to resin content. In this respect, increasing resin content from 2 to 6 percent resulted in increasing test values.

2. Moisture content at time of flaking affected physical properties significantly. At a resin content of 2 percent, values for MOR and internal bond were higher at low moisture content (26 percent). At 6 percent resin content, this same effect was evident for internal bond. Conversely, modulus of rupture at 6 percent resin content was higher at the high level of moisture content (116 percent).

3. Degree of atomization had no significant effect on modulus of rupture. For internal bond, however, test values were highest with fine spray at the 2 percent level of resin content. Conversely, at 6 percent resin content, test values were slightly higher for coarse spray.

Remarks

Several interesting findings have resulted from this study. Reasons for some results are not known entirely; in these instances, logical or reasonable explanations can be advanced. Some conclusions may be considered contradictory to established ideas or practices, but deserve discussion.

Fast-growth flakes appeared to have smoother surfaces than did slow-growth flakes. One explanation that appears reasonable relates directly to the flake-slicing operation. Action of the knife as it proceeds through a block

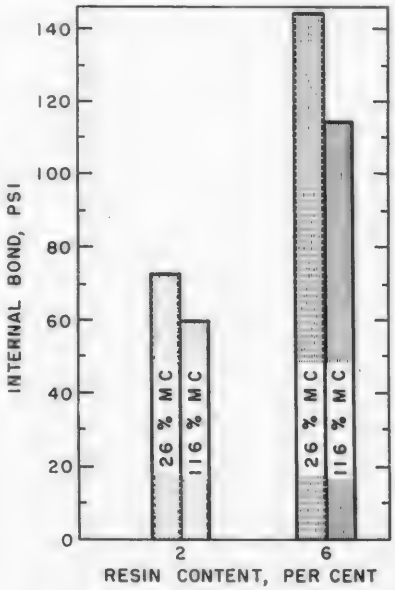

Fig. 12.—Interaction between resin content and moisture content at time of flaking. Each bar value represents a mean of 12 observations.

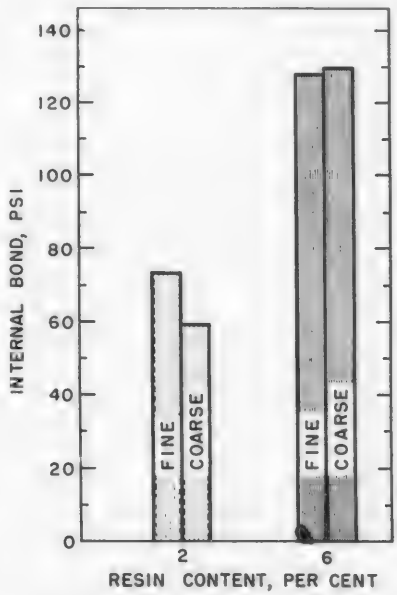

Fig. 13 —Interaction of resin content and degree of atomization. Each bar value represents a mean of 12 observations.

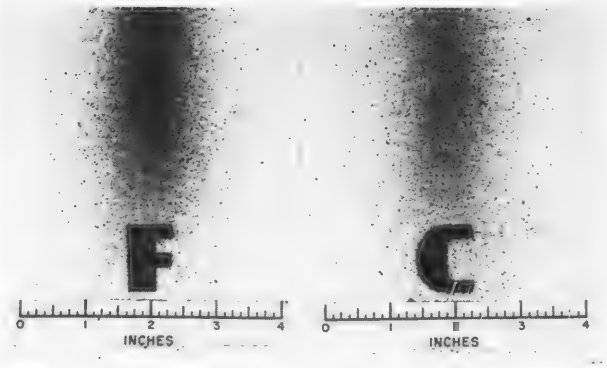

Fig. 6.—Pattern with spray of short duration: F, fine spray with 80 pounds atomizing air; C, coarse spray with 60 pounds atomizing air.

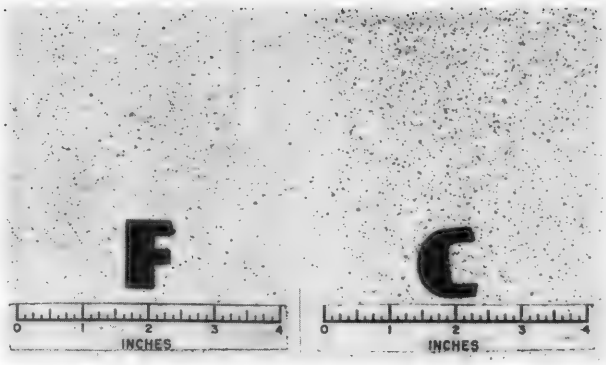

Fig. 7.—Pattern with paper dropped through spray: F, fine atomization with 80 pounds atomizing air; C, coarse atomization with 60 pounds atomizing air.

might vary according to the width of annual rings in the block. Under most efficient conditions, slicing action would be smooth and clean. With fast-growth material, this smooth knife-action might be accomplished easily because of long distance between rings. Slow-growth material, with rings close together, actually might set up an undesirable vibrating action detrimental to smooth slicing. In this respect, blade sharpness, speed of the slicing flywheel, and feed rate of blocks into the knives appear to be important factors.

Degree of internal damage resulting from the flake-slicing operation was anticipated to vary according to moisture content of blocks; that is, more damage was expected at the lower moisture content than at the higher. Investigation showed no appreciable internal rupture, however. Precautions taken to insure good flake-cutting conditions were assumed to have eliminated this type of injury. In addition, 26 percent moisture content probably was not an undesirably low level for slicing.

With one exception (MOR for boards containing 6 percent resin), test results indicated that flakeboard made from flakes cut at the lower moisture content level, 26 percent, had superior physical properties. This was an unexpected occurrence, since increased quality in flakes is anticipated from blocks cut at high moisture content. Also, soaking blocks in water prior to flaking would appear to be advantageous, since this practice supposedly would soften blocks and thus produce fewer damaged flakes. To explain why flakes cut at low moisture

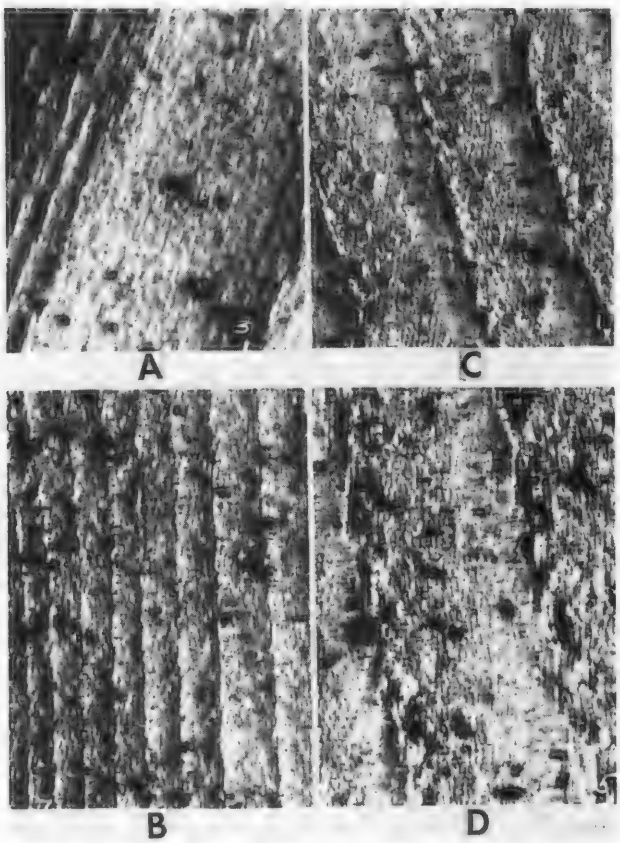

Fig. 8.—Resin droplets on flake surfaces: A, coarse spray and 2 percent resin; B, coarse spray and 6 percent resin; C, fine spray and 2 percent resin; D, fine spray and 6 percent resin.

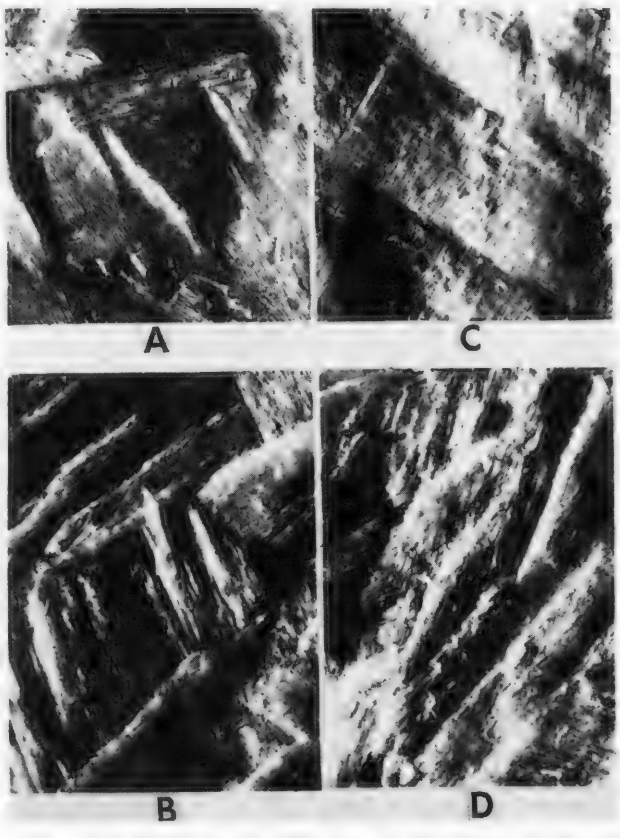

Fig. 9.—Flake-to-flake bonding observed on surfaces of cleaved board sections: A and B show areas where resin apparently was inefficient (resin droplets in upper left of photos); C and D show areas of considerable wood failure and efficient bonding.

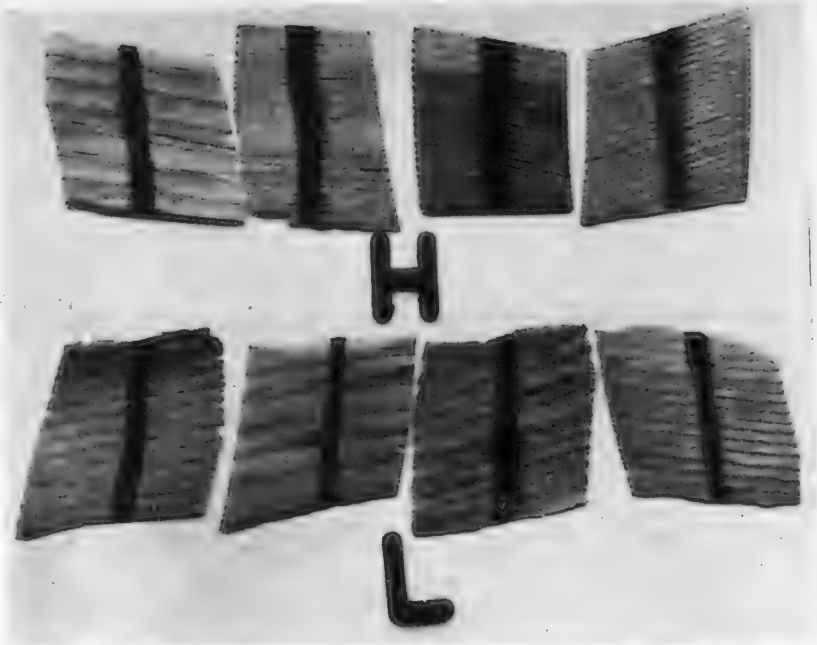

Fig. 14—Flakes showing difference in extent of stain spreading; H, flakes cut at high moisture content from water-soaked blocks; L, flakes cut at low moisture content from non-soaked blocks.

content produced superior boards, several ideas may be advanced.

Conceivably, there may be a moisture content for flaking above which quality of flakes declines. In other words, blocks with high moisture content in this study may have become too soft for good slicing. The fact that no noticeable differences in surface quality were observed between flakes cut at both moisture contents does not necessarily mean that differences did not exist, however. They may not have been discernible or obvious by the techniques used for evaluation.

To obtain desired high moisture content, blocks were immersed in water for about two months. Blocks for producing flakes at the low moisture content were not immersed in water. Certain water-soluble extractives may have been removed during soaking and so changed the chemical characteristics of the wood. A short, investigative study was made on flakes that had been cut from blocks conditioned in both manners. Purpose of this study was to measure pH, because pH often has an effect on resin curing. Flakes were ground into wood meal and placed in distilled water. Slurries were mixed thoroughly, and pH was measured on a standard meter. Results showed that flakes from blocks with high moisture content were slightly more acidic (pH 4.5) than flakes from blocks with low moisture content (pH 5.0). This small difference makes it doubtful that pH had any direct effect on gluability.

Flakes also were stained (Ameroid alkalinity indicator) to estimate pH. Results showed differences in pH that paralleled those measured on the meter. During this study of staining, another observation was made (see Fig. 14). Stain tended to spread outward along the annual rings more extensively on flakes cut from blocks with high moisture content than on flakes from blocks with low moisture content. This blotter-like effect was thought to be an indication of difference in absorptive ability. This could have an effect on gluing, as, for instance, it might cause undue penetration of resin on flakes cut from blocks with high moisture content.

Physical properties of flakeboards were improved markedly by increasing resin content. This procedure may not be in keeping with the idea of resin efficiency, however, which stresses minimum resin content. If resin is to be minimized, factors such as production of high-quality flakes (already discussed) and proper resin atomization become very important. The internal-bond test, which would be sensitive to inter-particle adhesion, showed that fine spray was desirable with 2 percent resin content. This effect might have occurred at the 6 percent level of resin content, but perhaps it was masked by the greater quantity of resin added. Nonetheless, if resin is to be used most efficiently, fine atomization apparently should be advocated.

Bibliography

1. Brumbaugh, J. 1960. Unpublished research on the effect of resin spot size on particle board properties. Pullman, Washington. Washington State Institute of Technology, Washington State University.
2. Elmendorf, A., and T. W. Vaughan. 1958. A survey of methods of measuring smoothness of wood. Forest Prod. Jour., 8 (10): 275–282.
3. Fehn, H. 1954. The manufacture of chip boards—a technological and industrial evaluation. Norsk Skogindustri, 8(11): 395–400. (Translation No. 2615, Commonwealth of Australia, CSIRO).
4. Hadley, D. 1959. Will particle board replace wood cores? Veneers and Plywood, 53: 11, 18–21.
5. Herdey, O. 1956. Synthetic resin and other additives. FAO-ECE, 19 p. (Paper 4.18 presented at the International Consultation on Insulation Board, Hardboard and Particle Board, Geneva, Jan. 21–Feb. 5, 1957).
6. Kitazawa, G. 1958. Personal letter. Assistant Head, Central Research Laboratory, Borden Chemical Co., Philadelphia, Pa.
7. Klauditz, W. 1958. Personal letter. Director, Institut für Holzforschung, Braunschweig, Germany.
8. Klauditz, W. 1956. The principles of particle board manufacture. FAO-ECE, 14 p. (Paper 5.26 presented at the International Consultation on Insulation Board, Hardboard and Particle Board, Geneva, Jan. 21–Feb. 5, 1957).
9. Kollman, F. 1952. Manufacture of medium-density wood-chip boards by the dry process. Holz als Roh- und Werkstoff, 10: 121–134.
10. Kollman, F. 1957. Resin application and equipment for blending resin with raw material particles. FAO–ECE, 10 p. (Paper 5.30 presented at the International Consultation on Insulation Board, Hardboard and Particle Board, Geneva, Jan. 21–Feb. 5, 1957).
11. Kollman, F. 1954. The present state of the technology of waste wood board manufacture. Holz als Roh- und Werkstoff, 12(4); 117–134.
12. Lynam, F. C. 1959. Factors influencing the properties of wood chipboard. Wood, 24: 18–20.
13. Marian, J. E. 1958. Adhesive and adhesion problems in particle board production. Forest Prod. Jour. 8 (6): 172–176.
14. Marra, G. G. 1960. Binders for particle boards. Madison, Forest Products Lab. Forest Service, U. S. Dept. of Agric. (Paper presented at the Symposium on Adhesives for the Wood Industry, Madison).
15. Marra, G. G. 1956. Some innovations in methods of producing special particles for board manufacture in the United States. FAO–ECE, 9 p. (Paper 5.28 presented at the International Consultation on Insulation Board, Hardboard and Particle Board, Geneva, Jan. 21–Feb. 5, 1957).
16. Stumbo, D. A. 1960. Surface texture measurements for quality and production control. Forest Prod. Jour. 10 (2): 122–124.
17. Suchsland, O. 1959. The strength of glue joints in wood obtained with minimum glue spread. Quarterly Bulletin, Vol. 41, No. 3. East Lansing, Michigan Agric. Expt. Station. Michigan State Univ., pp. 577–599.

Mechanical and Dimensional Properties of Flake Board[1]

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Ratio of flake length to thickness is a better indicator of flake board properties than is either dimension independently. Increases in resin spread increase bending strength only moderately.

PARTICLE SHAPE AND SIZE and resin content play an important role in determining particle board properties, costs, and manufacturing difficulties. This paper reports the effect of these variables on a number of physical and mechanical properties of oak flakeboard (1).[2] The reader is referred to a previously published paper (2) for a complete discussion of the experimental design and procedures used to manufacture small experimental flakeboard panels. Briefly, the study consisted of the evaluation of specimens cut from a single flakeboard panel (see Fig. 8 (2) for cutting diagram) manufactured for every possible combination of flake lengths of 0.5, 1, 2, and 4 inches, flake thicknesses of 0.006, 0.012, 0.025, and 0.050 inch, and resin spreads of 3.27, 6.54 and 13.07 grams of urea resin solids per square meter of flake surface area. Properties determined were:

Mechanical

- Flexure
  - Modulus of rupture
  - Fiber stress at proportional limit
  - Modulus of elasticity
- Screw withdrawal
- Tensile strength perpendicular to the face

Dimensional

- Thickness stability and springback
- Linear stability and springback.

[1] A 1959 Wood Award entry; revised and approved for publication Nov. 28, 1960.

[2] Numbers in parentheses refer to the Literature Cited at the end of this paper.

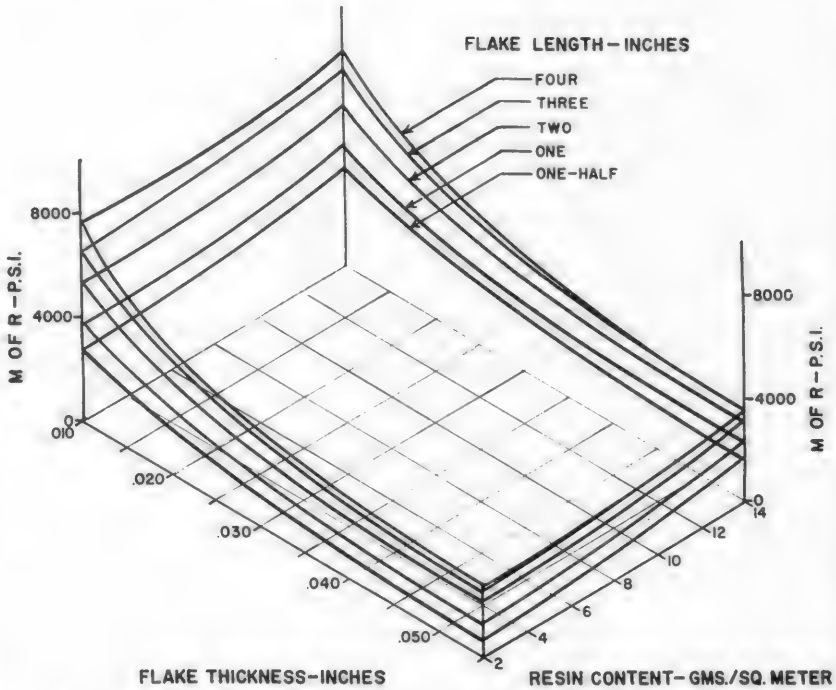

Fig. 1.—Regression surfaces for various flake lengths of modulus of rupture in terms of flake thickness and resin spread.

No additives other than resin were used. Table 1 gives the equivalent percentage resin content for these spreads and flake sizes.

The possible influence of a number of uncontrolled factors on test results was recognized in discussing modulus of rupture results, and the measures taken to minimize or eliminate these effects wherever possible were outlined (2). Essentially the same procedures were used before analysis of other strength properties wherever it appeared that the particular strength property might be influenced by folding and curling of flakes (which interfered with resin distibution) or variation in specific gravity (1). Average results of strength tests from which these effects have been largely removed are given in Table 2. Table 3 summarizes the results of analyses of variance performed on these data to determine the significance of main effects and their interactions on each of the above-listed mechanical properties. No corrections could be applied in the case of resin distribution or flake surface quality, but a close examination of test data indicates that these effects are considerably smaller than the main effects being studied (1).

Mechanical Properties

Flexure: Static bending tests were performed in accordance with ASTM Designation D 1037–52T except for a reduction in span (2).

Modulus of Rupture: The very substantial influence of flake dimensions and the more modest effect of resin content was presented previously (2) and will not be repeated here in detail. To further define the relationship between these variables, however, a multiple regression equation with the form

$$MOR = a + b_1L + b_tT + b_rR + b_{1/t}L/T + b_{l^2}L^2 + b_{t^2}T^2 + b_{t^2}R^2 + b_{(1/t)^2}(L/T)^2$$

was fitted to the average corrected MOR of each board where

- MOR = modulus of rupture in pounds per square inch
- L = flake length in inches
- T = flake thickness in inches
- L/T = flake length to thickness ratio.

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Table 1.—SURFACE AREA OF FLAKES AND RESIN CONTENTS USED TO OBTAIN REQUIRED SPREAD PER UNIT OF PARTICLE SURFACE AREA

Flake thickness, inches	Surface area		Percent resin[2] Resin spread—grams per sq. M.		
	in²/in³	M²/Kg[1]	3.268	6.536	13.072
0.006	337.3	18.7	6.11	12.2	24.4
0.012	171.6	9.52	3.11	6.22	12.4
0.025	84.0	4.66	1.52	3.04	6.08
0.050	44.0	2.44	0.80	1.60	3.20

[1]Specific gravity = 0.71.
[2]Computed on the basis of oven-dry weight.

Use of a digital computer and a prepared regression analysis program that eliminated non-significant terms at the 95 percent confidence level resulted in the following equation:

$$MOR = 2561.0 + 1279.5(L) - 105{,}970(T) + 9.7907(L/T) - 204.33(L)^2 + 1{,}095{,}453(T)^2 + 5.1894(R)^2.$$

The length-to-thickness ratio term was by far the most important. It had a simple correlation coefficient of 0.88, which is in agreement with previous observations (2). Regression surfaces calculated from the above equation for discrete levels of flake length are shown in Fig. 1. The multiple correlation coefficient of 0.985 indicates the closeness of fit.

Fiber Stress at Proportional Limit: Table 3 indicates that only the main effects of resin, length, and thickness had significant effects upon fiber stress at proportional limit. Plots of FS at PL against these variables are similar in character to the corresponding plots of modulus of rupture (2) but are more erratic. The relationship between flake length-to-thickness ratio and FS at PL is shown in Fig. 2. Several points representing board with a flake length of 4 inches that failed in shear were not considered in fitting the curve.

A regression analysis similar to the MOR analysis resulted in the following reduced equation, which had a multiple correlation coefficient of 0.951:

$$FS \text{ at } PL = 2223.1 + 50.178\,(R) + 24.1653\,(L/T) - 36.645\,(L)^2 + 0.01493(L/T)^2$$

Where FS at PL is in psi, and other notation is identical with the MOR equation. The simple correlation coefficient for the length-to-thickness ratio term of 0.756 was by far the highest of the equation.

Modulus of Elasticity: Table 3 shows that only the main effects of length and thickness are significant. The influence of these dimensions on MOE in general is similar to their effects on MOR (2). The relationship of MOE to length-to-thickness ratio is shown in Fig. 3, and again correlation is rather good. Several values unduly influenced by shear failures were not considered in fitting the curve.

Screw Withdrawal: This test was conducted in accordance with an established procedure (3) calling for withdrawal of a 1-inch No. 10 wood screw from the face of the specimen at a rate of 0.05 inch per minute after insertion to its full threaded depth into a ⅞-inch pilot hole. Resin spread and the length-thickness interaction were the only factors that significantly influenced maximum withdrawal load. The effect of resin spread is modest and consistent, as shown in Fig. 4; effects of both length and thickness were small and inconsistent.

Tensile Strength Perpedicular to the Face: A 2-inch square sample was glued between wood blocks and tested in tension at a head speed of 0.050 inch per minute. Tensile strength was low, averaging only about 71 psi, and so erratic that it was fruitless to attempt to extract much useful information from these tests. They have therefore been omitted from Table 2. Table 3 indicates the presence of a three-factor interaction between the main variables and, as is to be expected, a significant resin effect.

Dimensional Properties

Two linear and two thickness measurements were taken of a 2 by 8-inch dimensional stability sample from each board of the high-resin-spread group only after conditioning to equilibrium alternately at 50 and 90 percent relative humidity for three full cycles, which began at 50 percent. Figs. 5 and 6 (from data on the 2 by 0.025-inch flake size) are fairly typical of plots of cumulative dimensional change expressed as a percent of original dimensions. The actual dimensional change oscillates between the 50 and 90 percent lines shown. Two parameters, here termed springback and stability, were calculated from straight lines fitted to the 50 and 90 percent boundary lines. Springback, or non-recoverable dimensional change, was calculated as the slope (percent springback per cycle) of the 50 percent boundary line, and stability (percent), or recoverable dimensional change, was calculated as the vertical displacement of the 90 percent line above the 50 percent line at the 1½ cycle point. Both values, corrected for specific gravity differences, are given in Table 4 and are plotted in Fig. 7 to show the effects of flake size.

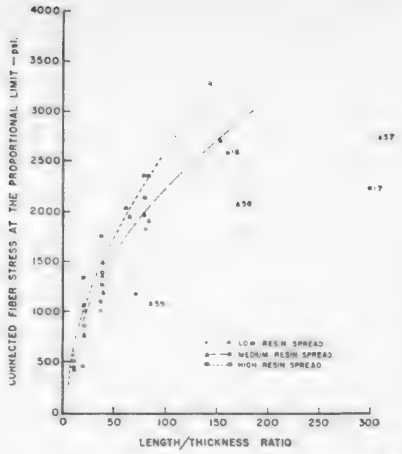

Fig. 2.—Effect of ratio of flake length to thickness on fiber stress at the proportional limit.

Linear stability is substantially affected by both flake dimensions as shown in Fig. 7C. Linear springback, Fig. 7A, appears to be influenced by flake size only when flake thickness is greater than 0.012 inch.

Thickness stability, Fig. 7D, also is practically unaffected by flake size when thickness is 0.012 inch or less. Thickness springback, Fig. 7B, increases rapidly as flake thickness increases.

It should be pointed out that a board bonded with a different resin could exhibit dimensional change patterns considerably different from those obtained with the urea resin used in this study. A phenolic resin might give quite different springback properties.

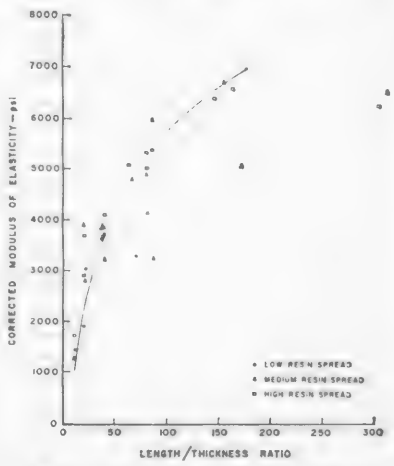

Fig. 3.—Effect of ratio of flake length to thickness on modulus of elasticity.

Table 2.—AVERAGE CORRECTED RESULTS OF STRENGTH TESTS[1]

Property	Flake length inches	Resin spread: Low — Flake thickness 0.001 inch: 6	12	25	50	Medium: 6	12	25	50	High: 6	12	25	50
MOR psi	½	2197	2423	1612	800	3715	2477	1888	1554	4871	2958	2490	1107
	1		3532	2004	1950		3631	2040	1580		3974	2440	1684
	2						5255	2948	2256		5522	3914	2619
	4						1636	4200	2634		6841	4884	3858
FS at PL psi	½	1178	1103	852	432	1946	1359	1053	424	2031	1739	1331	502
	1		1822	1008	463		1963	1182	751		2334	1392	1016
	2						2704	1903	1491		3288	2143	1273
	4						2766	2082	1078		2500	2594	2348
MOE 1000 psi	½						382	384	120		404	362	166
	1						483	316	274		528	380	284
	2						666	491	366		636	495	361
	4						653	504	319		626	654	530
Screw withdrawal lbs.	½	188	253	246	229	408	310	366	216	360	387	409	322
	1	316	332	240	284	411	312	428	282	372	384	408	358
	2	384	356	246	310	359	522	371	356	392	417	436	415
	4	222	200	266	378	236	370	347	414	364	464	470	485

[1]Values reported are the average of two tests, each corrected for its specific gravity difference from the average specific gravity of all boards. Correction was based on a straight line fitted to the within board differences in specific gravity of all boards.

Discussion

The ability of bonds between flakes to transmit forces to which they are subjected by the various tests offers a rational, although rather speculative, explanation of the results obtained. The obvious forces imposed by mechanical testing and by the tendency for differential dimensional change of flakes with changing humidity conditions are added to existing forces that arise from the tendency of flakes which were deformed during the pressing operation to recover their original shape. Application of heat in the presence of moisture during the pressing operation and subsequent relaxation greatly reduce these recovery forces. That they may depend greatly on flake thickness is apparent when it is realized that the force required to bend a flake to a given radius of curvature increases with the cube of the flake thickness.

Bond strength is obviously dependent upon both resin spread and the bond area between flakes. The latter is a direct function of both flake length and width. Flake dimensions also may influence bond area through their influence on the number and size of area-reducing voids present in the finished board. Tension and compression in the plane of the panel, bending, and the tendency of flakes to change dimension more in width than length in response to changes of moisture content produce normal stresses that act in the plane of the panel. These are largely resisted by those flakes whose grain direction is more or less parallel to the direction of stress due to the high elastic modulus of wood along the grain as compared to the across-the-grain direction. The proportion of flakes so oriented would be constant and independent of flake geometry if a random distribution of flake orientation is assumed. As has been pointed out by Marra (4), increasing flake length increases the available bond area so that the full strength of the flake is more effectively utilized. The same argument applies to an increase in length-to-thickness ratio due to a reduction of flake thickness. The above discussion seems to offer the most reasonable explanation for the correlation of flexural strength with flake length-to-thickness ratio.

The comparatively small and somewhat inconsistent influence of flake size on springback and stability in both directions when flake thickness is 0.012 inch or less seems to indicate

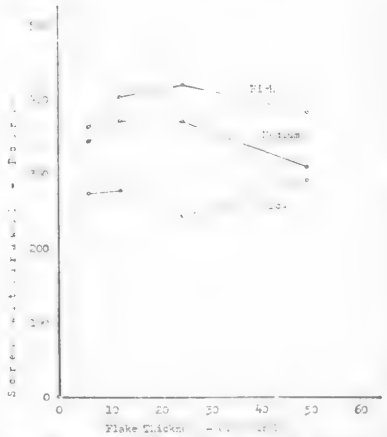

Fig. 4.—Effect of flake thickness on screw withdrawal load.

that the resin bonds are able to resist the tendency of relatively thin flakes to change dimension unequally along and across the grain. The reduced bond area in relation to the forces tending to produce unequal dimensional change offers a logical explanation of the rapid increases of linear springback and stability that accompany increases in flake thickness or decreases in flake length when thickness is above 0.012 inch. The rapid increase in thickness springback as flake

Table 3.—SUMMARY OF ANALYSIS OF VARIANCE OF STRENGTH PROPERTIES

Source	Modulus of rupture: Mean square	"F" ratio	Fiber stress at proportional limit: Mean square	"F" ratio	Modulus of elasticity: Mean square	"F" ratio	Screw withdrawal: Mean square	"F" ratio	Internal bond: Mean square	"F" ratio
Main effects										
Resin	3,382,470	15.53**	262,144	6.8*	18,213	3.9	126,783	31.3**	5,088.2	7.3*
Length	18,564,635	29.67**	3,014,215	78.7**	151,871	32.3**	21,451	1.6	2,906.3	4.1
Thickness	25,217,658	40.24**	4,862,810	127.0**	242,410	60.6**	3,363	0.3	262.4	0.4
Two-factor interactions										
Resin—length	209,104	0.92	36,052	1.1	8,308	2.1	4,983	1.3	132.35	0.2
Resin—thickness	66,721	0.29	81,891	2.5	4,350	1.1	6,033	1.6	78.05	1.1
Thickness—length	626,784	2.74*	73,039	2.2	6,884	1.8	13,189	3.5**	1,376.89	2.0
Three-factor interaction										
Resin—length—thickness	78,471	0.29	8,940	0.3	4,404	1.2	4,800	1.4	704.44	10.7**
Error term										
Within boards	266,383	----	35,204	----	3,782	----	3,396	----	65.66	----

**Indicates significance at 1 percent level of probability.
*Indicates significance at 5 percent level of probability.

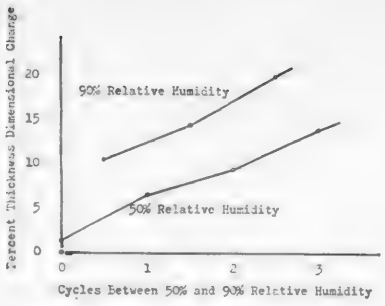
Percent Thickness Dimensional Change
90% Relative Humidity
50% Relative Humidity
Cycles Between 50% and 90% Relative Humidity

Fig. 5.—Effect of number of cycles on thickness dimensional change.

Table 4.—CORRECTED SPRINGBACK AND DIMENSIONAL STABILITY

Board number	Thickness		Linear	
	Springack Percent per cycle	Stability Percent	Springback Percent per cycle	Stability Percent
1	0.944	4.38	0.016	0.27
2	1.500	4.66	0.023	0.28
3	2.935	6.61	0.090	0.44
4	8.480	14.51	0.529	0.83
6	1.302	4.37	0.015	0.21
7	1.745	3.93	0.019	0.21
8	3.445	7.01	0.049	0.24
9	9.246	13.53	0.276	0.78
11	1.269	4.21	0.010	0.26
12	1.170	3.87	0.007	0.14
13	4.238	7.61	0.060	0.20
14	14.689	10.85	0.200	0.38
16	1.256	4.13	0.015	0.24
17	1.785	4.53	0.014	0.17
18	1.886	4.59	0.021	0.19
19	5.962	9.59	0.176	0.63

thickness increases could be the result of greater bending stresses incorporated in the flakes at pressing, as mentioned earlier. The cause of the reduction in dimensional stability as flake thickness increases is not so apparent, but a contributing factor may be that a considerably smaller proportion of the board is made up of the relatively non-hygroscopic and non-swelling resin than when thinner flakes are used, since for this study resin addition was based on flake surface area.

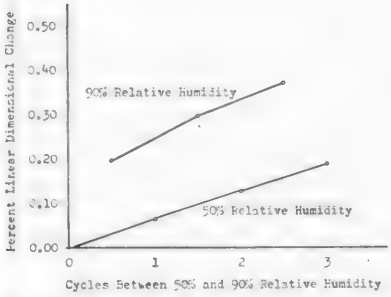
Percent Linear Dimensional Change
90% Relative Humidity
50% Relative Humidity
Cycles Between 50% and 90% Relative Humidity

Fig. 6.—Effect of number of humidity cycles on linear dimensional change.

Conclusions

1 .Flake length-to-thickness ratio is a better measure of the influence of flake length and thickness upon bending strength and stiffness than either of the two dimensions considered separately, and a high correlation between length-to-thickness ratio and these properties can be expected.

2. Increases of resin spread (percent if particle geometry is held constant) can be expected to improve bending strength only to a moderate degree. Stiffness is not materially influenced by resin spread.

3. Only slight improvement in screw withdrawal resistance can be expected to accompany increases of resin spread. Influences of flake size are small, if present, except for an improvement of withdrawal as the length of excessively thick flakes is increased.

4. Both linear and thickness springback continue to increase for three and probably more cycles of relative humidity change. Dimensional stability does not appear to change materially as cycling is continued.

5. Thickness springback increases as flake thickness is increased, particularly in the region above 0.012 inch.

6. The use of longer flakes has no effect upon linear springback when flakes of less than 0.012 inch are employed, but reduces springback when thicker flakes are used.

7. Neither thickness nor linear stability are greatly affected by changes of flake length or thickness for flakes below 0.012 inch in thickness. Above this point both properties decreased with increasing thickness and decreasing length.

From the practical standpoint of improving board properties without incurring additional cost, increasing flake length appears most promising, although handling and forming problems would undoubtedly develop. The prospect of increasing flake thickness as a means of reducing surface area and hence percent resin should be approached with some caution, since stability and springback properties may be impaired if carried too far.

Literature Cited

1. Post, Paul W. 1959. The effect of particle geometry and resin content on the physical and mechanical properties of oak flake board. Unpublished thesis. School of Forestry, Pennsylvania State Univ., Univ. Park, Pennsylvania.

2. Post, Paul W. 1958. Effect of particle geometry and resin content on bending strength of oak flake board. Forest Prod. J. 8:317–322.

3. National Woodwork Manufacturers Association. 1957. Recommended testing procedures for wood particle board. Chicago.

4. Marra, George A. 1954. Discussion following article by Turner. Forest Products Journal 4:210–223.

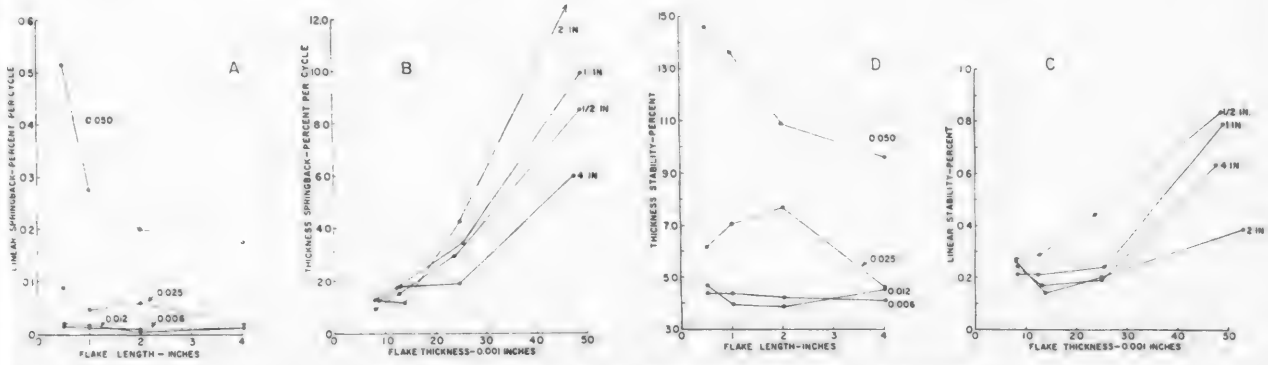

Fig. 7.—Effect of flake size on dimensional stability and springback.

For Soil Conditioning and Mulching[1]

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Wood wastes can have beneficial effects on soil, but care must be taken to avoid nitrogen deficiency. Methods are: (1) including nitrogen fertilizers with raw wood wastes, (2) chemical processing to incorporate nitrogen, and (3) composting.

USE OF SAWDUST, tow, chips, and ground bark for mulching and soil conditioning is rapidly increasing, especially in the Pacific Northwest. Although the benefits to be gained and precautions to be observed have been discussed in several recent reports (1, 6,. 24, 25, 27),[2] the widespread interest in this utilization of wood residues merits review of the fundamental principles and factors involved. Where previously published data is presented for comparison, reference is given. Additional information on evaluation and comparison of representative wood residues used on the soil is presented, and some commercially available products are described. Except for available-nitrogen requirements, the need for additional fertilization to insure maximum plant growth on soils amended with wood and bark products has been considered elsewhere (22, 27).

Function of Mulches and Soil Conditioners

The chief benefits to be derived from relatively inert or slowly decomposable wood wastes added to soil are increased moisture retention, greater aeration, and better tilth. Mulches retard erosion, hinder weed emergence, reduce evaporation, and retain warmth. Decomposition of organic materials on or in the soil results in complex transformations of carbon and nitrogen compounds, and eventually supplements the native humus. Soil type and composition of added organic materials are determining factors in the amount of humus formed and held.

Humus is not only essential for superior tilth, but it also serves as the chief store of nitrogen, phosphorus, sulfur, and other nutrients rendered slowly available by microbial action in the soil. Bacteria and other microorganisms transform potential fertility of complex compounds into simpler forms or "active fertility", which plants can use. This applies to inorganic as well as to organic materials; carbon dioxide and acids produced in various microbial transformations exert solvent action on soil minerals to liberate available potassium, calcium, and other nutrients. Thus, a soil conditioner may function by modifying not only physical characteristics of the soil but also its chemical and microbial properties.

Sawdust and bark mulches and soil conditioners may be more or less subject to certain disadvantages: competition for available nitrogen and to a lesser extent for other nutrients, retention of excess moisture, retardation of temperature increase following cold periods, decrease of pH if material was strongly fermented, packing of fine materials, and some objectionable features due to slivers and dust in handling. On the other hand, mulches of these materials are easier to apply, longer lasting, less susceptible to blowing and fire, and more pleasing in appearance than straw or leaves.

Evaluation of Residues

Evaluation of a given wood residue for soil improvement should take into account the various advantages and disadvantages mentioned. In addition, consideration must be given to availability of supply, transportation expense and cost of application, uniformity of material, and nature of soil and crop to be treated.

A comprehensive appraisal of wood residues also requires consideration of such other properties as ion-exchange capacity, particle-size distribution, proximate chemical composition, carbon-to-nitrogen ratio, availability of nitrogen, rate of microbial decomposition with particular reference to carbon and nitrogen transformations, and the ultimate influence on plant growth under given conditions. Methods and results obtained in studies at the Oregon Agricultural Experiment Station are outlined in the following presentation with pertinent citations.

Particle Size of Residues: Because particle size affects reactivity and rate of decomposition, mechanical analyses are significant. Results of fractionations with Tyler standard screens are shown for some representative products in Table 1. Fraction size is also important for use of wood wastes on the soil. Chips, shavings, millrun sawdust, and gang sawdust make good mulches; resaw sawdust packs tightly and may excessively retard aeration and moisture penetration. Sawdust in any form is satisfactory for incorporation if well mixed with the soil, but chips and thick shavings may be too coarse to be desirable for this purpose. Studies to determine the specific influences of particle size have not been made.

The presence of appreciable amounts of bark in millrun sawdust is not disadvantageous for general uses. An estimated 15 percent was present in the sawdust (Table 1) used on field plots (27); this was concentrated largely in 5-mesh, 40-mesh and finer fractions.

Carbon-to-Nitrogen Ratio and Nitrogen Availability: Wood and bark, like other crop residues, are high in carbon but they are exceptionally low in nitrogen and other fertilizer ele-

[1] Technical Paper No. 1262, Oregon Agricultural Experiment Station, originally presented at the Wood Industries Conference, Sept. 10, 1959, in Portland, Oregon. Extensively revised May, 1960.

[2] Numbers in parentheses refer to the Literature Cited at the end of this paper.

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ments, which are present mainly in the ash (Table 2). Different samples of a given kind of carbonaceous waste can vary considerably in carbon-to-nitrogen ratio as a result of only slight percentage differences in their low nitrogen content. Thus the ratio for the several samples of Douglas-fir bark shown in Tables 2, 3 and 5 range from about 300 to 500. If the ratio is much wider than 25:1, microorganisms carrying on the decomposition compete with plant roots for available nitrogen. When organic matter has a nitrogen content of about one percent or less, all the nitrogen is consumed by microorganisms in utilizing the carbon, mainly for energy, and in addition they compete with higher plants for more available nitrogen from the soil or fertilizers so long as oxidizable carbon compounds remain. An extended nitrogen starvation may result and limit microbial development as well as plant growth. This condition can be corrected by addition of nitrogenous fertilizers.

When the nitrogen content is from two to two and one-half percent, giving a carbon-to-nitrogen ratio of 25:1 to 20:1, only temporary nitrogen depletion results and liberation of ammonia follows. With a higher percentage of nitrogen, or carbon-to-nitrogen ratios narrower than about 20:1, requirements or organisms active in the decomposition are more than satisfied and ammonia is liberated by ammonification throughout the process. Ammonia thus released is immediately available to plants, either as such or after oxidation to nitrate by nitrifying bacteria.

While a wide carbon-to-nitrogen ratio always retards decomposition, a narrow ratio does not necessarily promote it because the chemical structure in which nitrogen occurs determines its availability. Humus with a ratio of 10:1 to 12:1, leather with a similar ratio, ammoniated bark with a ratio of 15:1, and urea-resin bonded particle board waste with a ratio of 29:1 all are very slowly decomposable because of slow availability of the nitrogen.

Table 1.—MECHANICAL ANALYSIS OF SAWDUST, BARK, AND WHEAT STRAW

	Percentage retained on Tyler standard screens of indicated mesh									
	5	10	20	40	60	80	100	150	200	<200
Sawdust										
Douglas-fir, mill run[1]	17.7	18.6	33.2	18.1	5.6	2.6	1.8	1.8	0.7	0.6
Douglas-fir, gang saw	0.0	29.3	40.9	23.3	3.3	1.3	0.6	0.5	0.5	0.2
Milled[2]	0.0	0.0	21.0	52.8	15.1	3.4	2.3	2.5	1.7	1.1
Milled[3]	0.0	0.0	0.0	0.0	0.7	6.5	12.3	22.0	20.4	37.7
Hemlock, gang saw	0.0	30.3	41.7	20.9	3.6	1.3	0.5	0.5	0.4	0.3
Cedar, gang saw	0.0	30.6	43.2	18.9	4.9	1.3	0.8	0.5	0.3	0.1
Pine, resaw	0.0	0.0	35.7	46.6	11.3	3.0	1.2	1.1	0.7	0.7
Oak, resaw	0.0	0.1	45.1	38.8	8.1	3.2	1.1	1.7	0.8	1.0
Douglas-fir bark, ground[4]	2.6	20.3	20.0	17.7	15.7	8.0	4.2	4.0	3.6	4.3
Wheat straw, milled[2]	0.0	0.5	31.6	38.5	12.9	6.8	3.0	3.0	1.9	1.9
Wheat straw, milled[3]	0.0	0.0	0.0	0.0	6.4	18.4	18.9	16.7	27.2	12.1

[1] Used in field trials.
[2] Hammermilled through 10-mesh screen. Used in greenhouse experiments.
[3] Hammermilled through approximately 60-mesh screen. Used in laboratory experiments.
[4] Used for ammoniation experiments.

Nitrogen in different compounds applied to soil differs in availability to plants. This must be considered in fortifying wood or bark residues to overcome their nitrogen deficiency. Ammonium and nitrate nitrogen are water-soluble and immediately available; however, nutritional preference varies with kind and age of plant, pH, and concentrations of other ions in the soil solution (28). Ammonium nitrate may be a fertilizer of choice because it provides both cationic and anionic nitrogen. Nitrate is readily leached from soil, but the ammonium ion is held by the organic and inorganic cation exchange complexes.

Nitrate nitrogen in excess of two to five parts per million is toxic to many plant species. Organic nitrogen compounds most likely to be applied to soil are readily attacked by microbes, which release the nitrogen as ammonia. Plant and animal proteins, amino acids, urea and many heterocyclic and other complex nitrogen compounds are more or less rapidly ammonified. Keratins, which are scleroproteins characteristic of horns, hoofs and feathers, yield ammonia slowly. Calcium cyanamid, napthylamine, phenylamines, protein of dead bacterial cells, and urea-formaldehyde resins (9) are relatively resistant to ammonification.

In formulating a wood-waste soil conditioner/fertilizer, a mixture of soluble and slowly available nitrogen sources could be advantageous.

Residue Composition and Decomposability

Because plant residues are of mixed composition (Table 3), they are acted upon in the soil by various species of microbes in several well-defined stages of decomposition. Molds and many bacteria attack carbohydrates and proteins rapidly, while *Streptomyces* have exceptional ability to decompose lignins and other highly resistant residues. Different kinds of organisms predominate as part of the substrate is more or less rapidly and completely decomposed, part is reassimilated, and part is resistant and very slowly transformed. Depending on the frequency with which fresh organic matter appears on or in the soil, the several stages of decomposition are more or less concomitant. The net result is a circulation of carbon, nitrogen, and other nutrients in the cycles of nature,

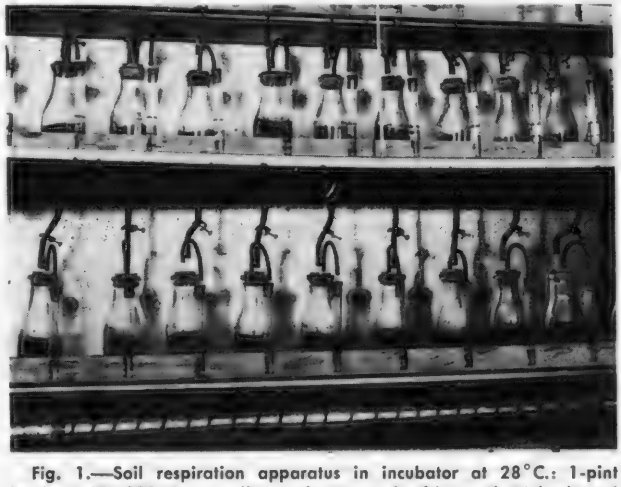


Fig. 1.—Soil respiration apparatus in incubator at 28°C.: 1-pint bottles with 200 gram soil samples treated with sawdust, bark and nitrogen sources. Evolved CO_2 is collected by 1N NaOH in small tubes and determined by titration.

Table 2.—CARBON AND NITROGEN IN FARM AND FOREST PRODUCTS USED AS MULCHES AND SOIL CONDITIONERS (3)

Material	Ash Percent	Total carbon Percent	Kjeldahl nitrogen Percent	C/N
Alfalfa hay	8.79	43.15	2.34	18
Pea vines	8.50	44.02	1.50	29
Wheat straw	8.54	44.70	0.12	373
Corn cobs	1.58	46.87	0.45	108
Douglas-fir bark				
Young	0.69	51.66	0.17	304
Old	0.57	58.56	0.20	293
Cork (>20 mesh)	0.41	59.32	0.13	456
Bast (60–80 mesh)	0.69	54.29	0.11	494
Fines (80–100 mesh)	0.70	54.08	0.12	451
Dust (<100 mesh)	0.14	57.00	0.18	317
Douglas-fir sawdust				
Mill run, fresh	1.48	51.00	0.07	728
Mill run, 2 mo.[1]	1.61	49.98	0.08	625
Mill run, 3 years[1]	7.99	47.01	0.33	142
Sawdust, resaw				
Douglas-fir	0.17	49.80	0.05	996
Red alder	1.21	49.63	0.37	134
Western red cedar	0.29	51.05	0.07	729
Western hemlock	0.35	49.74	0.04	1244
Ponderosa pine	0.33	53.18	0.05	1064
Sitka spruce	0.22	51.50	0.05	1030
Moss peat	3.12	48.29	0.83	58
Douglas-fir pitch	0.00	72.70	0.00	----

[1] Weathered.

Table 3.—PROXIMATE ANALYSIS OF DOUGLAS-FIR, ALFALFA, AND WHEAT STRAW (5)

Material	Ash Percent	Alcohol-benzene extract[1] Percent	Alcohol extract[1] Percent	Hot water extract[1] Percent	Holocellulose Percent	Klason lignin Percent	Crude protein Percent	Total carbon Percent	C/N ratio
Douglas-fir:									
Bark	0.5	13.7	0.2	2.5	42.2[2]	41.6[2]	0.4	54.0	490
Sapwood	0.3	3.5	0.1	2.7	52.2	37.4	0.0	49.4	550
Heartwood	0.3	8.1	0.3	4.2	60.6	25.9	0.0	51.5	430
Needles	5.6	36.6	0.3	12.1	20.5	20.3	6.0	55.8	58
Alfalfa hay	8.8	15.7	0.6	16.9	29.8	14.3	14.6	43.2	18
Wheat straw	8.5	8.0	0.4	5.0	62.9	13.5	0.8	44.7	375

[1]Extracts reported on successive extraction basis.
[2]Not typical wood lignin; contains bark phenolic acids and their hydroxy fatty acid esters (23). Holocellulose is likewise an approximation.

Table 4.—DECOMPOSITION OF SOIL-INOCULATED ORGANIC MATERIALS WITH AND WITHOUT NH_4NO_3 ADDITION EQUIVALENT TO 0.7 PERCENT N (5)

Material	Total carbon Percent	C:N ratio		Weight loss in 42 days at 28°C and 60% saturation	
		Original	With NH_4NO_3	With NH_4NO_3 Percent	Without NH_4NO_3 Percent
Pea vines	45.30	17	13	59	58
Corn cobs	46.87	108	41	44	15
Oat straw	47.16	171	48	35	14
Wheat straw	44.70	373	55	31	15
Douglas-fir sawdust	49.84	623	64	15	11

and the major end products are carbon dioxide, water, ammonia, resistant residues, and microbial cells (5).

The most resistant organic residues are lignins and proteins of dead bacterial cells. These accumulate and mutually react to form the humus nucleus, which absorbs iron, aluminum, and silicon compounds and cations to become the complex of rather indefinite residual substance commonly referred to as humus. The nitrogen content of this complex is high, and the carbon-to-nitrogen ration is commonly near 10:1. It ranges from 8:1 to 12:1 in different soils and at different depths. Nevertheless, humus is only slowly decomposable, and only by specialized bacteria. For this reason, it represents a store of slowly but continually available nitrogen in soil so long as crop residues are returned. If subsequent plant residues were excluded, the final decomposition product of the humus would be an accumulation of dead bacterial cells, with a carbon-to-nitrogen ratio of 5:1.

It is thus evident that the soil organic matter in the usual sense, meaning the more or less humified material distributed in the soil, is a complex resulting from microbial action on all kinds of dead organisms and their products. Partially decomposed or partially humified organic matter can be built up, but it is more difficult to maintain than is the original humus content. Living organisms require food, and the supply, particularly with respect to carbon and nitrogen, must be maintained. For cultivated soils this requires the use of crop residues and often the use of fertilizers.

More resistant materials persist longer in the soil and exert more extended effects than readily decomposable substances. The rate of decomposition under given conditions of moisture, temperature, aeration, and other factors imposed by soil type is determined by mechanical condition, physical-chemical structure, and chemical composition. Most proteins of plant and animal origin are rapidly decomposed, and, if nitrogen is adequate, so also are sugars. Celluloses are decomposed less rapidly, and lignins very slowly. Wood residues are therefore most persistent. This is advantageous in providing longer lasting mulches and more prolonged effects when incorporated in the soil. It may be noted also (Table 4), that decomposibility of resistant carbonaceous materials such as sawdust is not greatly enhanced by addition of available nitrogen. The primary rate of decomposition of plant residues of mixed composition and wide carbon-to-nitrogen ratio responds to added nitrogen to a degree largely dependent upon their water-soluble carbonaceous constituents (Table 5), which are responsible for initial nitrogen demand. Addition of 20 pounds of fertilizer nitrogen per ton of Douglas-fir sawdust or wheat straw mixed with soil generally promotes preliminary rapid decomposition without nitrogen starvation. Cold water extract of fresh sawdust amounts to approximately 5 percent of the total substance, while that of the wheat straw is close to 8 percent. The straw extract, however, contains more nitrogen and its carbon-to-nitrogen ratio is narrower than that of sawdust. Scholler lignin is essentially free of nitrogen but, because of its inherent resistance, its decomposition is not significantly accelerated by supplemental nitrogen.

Laboratory Studies

Although the value of organic material as a soil conditioner or fertilizer is ultimately determined by crop response under practical field conditions, chemical analyses and microbial tests in the laboratory yield valuable preliminary or supplemental information rapidly. Knowledge of the carbon and nitrogen transformations resulting from additions of organic matter, whether as fertilizer or as amendment, to the soil is particularly useful in estimating effects upon available nitrogen and accumulation of desirable organic residues.

Comparative rates of decomposition are usually determined by soil respiration techniques (6) in which excess carbon dioxide evolved from soil treated with organic matter over that evolved from soil only serves as the index. Two hundred or 500 gram portions of soil are usually used (Fig. 1). Untreated soil serves as a control, while standard 60-mesh organic additions, each equivalent to 2000 p.p.m. carbon, permit direct comparisons of respiration data obtained during incubation. The influence of additions of available nitrogen and other supplements can be determined from their effects on evolution of carbon dioxide. For material containing 50 percent carbon, the actual addition to the soil to give 2000 p.p.m. carbon would amount to 0.4 percent, corresponding to 4 tons per acre furrow slice (6–2/3 inches) or 2,000,000 pounds.

In calculating extent of decomposition, carbon dioxide evolved from soil only is subtracted from that evolved by soil treated with organic material; the

Table 5.—CARBON, NITROGEN, AND COLD WATER EXTRACT IN DOUGLAS-FIR, ALFALFA, AND WHEAT STRAW (5)

Material	Total carbon Percent	Kjeldahl nitrogen Percent	C:N ratio Percent	Cold-water extract			
				Total Percent	Reducing sugars Percent	Kjeldahl nitrogen Percent	C:N[1] ratio
Douglas-fir:							
Bark	53.97	0.11	491	1.9	0.79	0.04	1250
Sapwood	49.36	0.09	548	1.0	0.14	0.09	556
Heartwood	51.51	0.12	429	4.8	0.77	0.13	385
Needles	55.75	0.96	58	22.0	5.65	0.16	313
Alfalfa hay	43.15	2.34	18	23.1	2.70	1.13	44
Wheat straw	44.70	0.12	373	7.8	3.98	0.48	104

[1]Approximate; based on C = 50 percent.

carbon equivalent of this net value, divided by the amount of carbon added in the treatment and multiplied by 100 gives the percent "apparent decomposition". The term "apparent" is used because studies on substrates labeled with isotopic carbon (C^{13}, C^{14}) have shown that some additional carbon dioxide is derived from native soil organic matter whenever microbial activity is increased by organic additions (20). Apparent decomposition values are useful for comparisons and, in most cases, probably do not differ greatly from absolute values, which must be determined by more elaborate techniques.

Table 6 presents data showing relative decomposability of sawdust and some other organic materials compared to dextrose, which is a rapidly decomposable sugar. Alfalfa and pea vines, which have a favorable carbon-to-nitrogen ratio, decomposed rapidly, while wheat straw, being deficient in nitrogen, decomposed about half as extensively in six weeks. Alder sawdust gave off carbon dioxide almost as rapidly as wheat straw, but fir sawdust decomposed only one-half as much. Scholler lignin was most resistant.

It is noteworthy that the pitch showed relatively rapid decomposition. This solid white pitch from a Douglas-fir wood pocket was ground to pass 60-mesh. Unlike pitch wood or masses of pitch that are quite durable in the soil, it presented an extensive surface to microbial attack.

Results obtained for various kinds of sawdust and other materials with a different soil are given in Table 7. It can be seen that Scholler lignin and moss peat and red rot, which are largely ligneous residues, were decomposed only very slowly.

The effect of added available nitrogen as shown by carbon dioxide production is often anomalous, less carbon dioxide eventually being evolved than without the nitrogen (Fig. 2). The cause of this remains undetermined. It is not likely to be due to decrease in pH, except where ammonium sulfate is used as the source of nitrogen on poorly buffered sandy soils. It is possible that added nitrogen relieves soil microorganisms of the necessity of decomposing nitrogenous soil organic matter to satisfy their nitrogen requirements, however, thus decreasing the total carbon dioxide given off even though the added organic matter may be more extensively decomposed. Assimilation of more carbon with added nitrogen also occurs, but this is relatively minor in extent. Practical field experience as well as weight-loss determinations (Table 4), which include oxygen and hydrogen, attest to more rapid decomposition attained when available nitrogen is added to materials of wide carbon-to-nitrogen ratio. Results will vary with different soils, under different conditions, and with physical and chemical nature of the organic material.

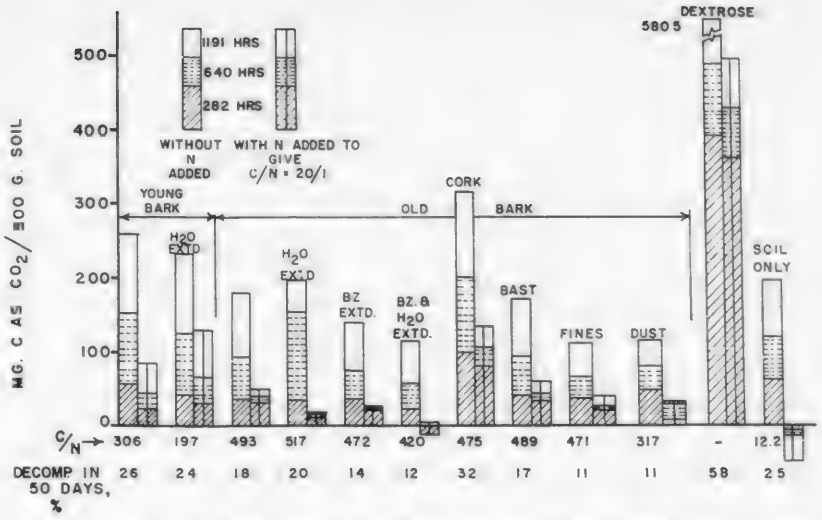


Fig. 2.—Cumulative CO_2 evolution during decomposition of Douglas-fir bark additions equivalent to 2000 p.p.m. carbon in Chehalis silty clay loam soil. Value for soil only substracted.

Influence of Residues on Plant Growth

Greenhouse pot experiments have been used to study the influence of incorporated sawdust on growth of sunflowers and barley on a silty clay loam soil (6). The sawdust and other residues used were ground to pass 10-mesh. Without added nitrogen, Douglas-fir sawdust at 10 tons per acre 6 2/3 inches (2,000,000 pounds of soil), equivalent to 1 percent by weight, had no significant effect, but with ammonium nitrate significant yield increases over ammonium nitrate without sawdust were obtained. At 100 tons per acre, the sawdust was highly depressive to plant growth. Adjustment of the carbon-to-nitrogen ratio to 50:1 prevented this depression and gave yields greater than the corresponding ration with sawdust at 10 tons per acre. A 20:1 ratio could not be used with the larger rate of saw-

Table 6.—DECOMPOSITION OF ORGANIC ADDITIONS EQUIVALENT TO 2000 P.P.M. CARBON IN NEWBERG SANDY LOAM SOIL AS INDICATED BY CO_2 EVOLUTION IN 42 DAYS (5)

Addition	C/N ratio	Apparent decomposition[1] Percent
Dextrose	---	60
Alfalfa hay	18	57
Pea vines	17	53
Wheat straw	447	31
Douglas-fir pitch	---	28
Alder sawdust	134	28
Douglas-fir needles	58	19
Walnut leaves	26	16
Douglas-fir sawdust	142	14
Scholler lignin	881	5
Soil only (0.51% C)	10	6

[1] $1 - \frac{(\text{C as } CO_2 \text{ from soil+substrate}) - (\text{C as } CO_2 \text{ from soil alone})}{(\text{C added in substrate})} \times 100$

Table 7.—APPARENT DECOMPOSITION OF SAWDUST AND OTHER ORGANIC ADDITIONS EQUIVALENT TO 2000 P.P.M. CARBON IN CHEHALIS SILTY CLAY LOAM SOIL AFTER 50 DAYS INCUBATION (5)

Addition	C/N ratio	Apparent decomposition: Without added nitrogen Percent	Apparent decomposition: With NH_4NO_3 to give C/N = 20/1 Percent
Dextrose	---	55.2	44.3
Corn cobs	105	49.6	46.6
Wheat straw	37	48.3	46.9
Rice hulls	72	33.5	24.7
Pine sawdust	1023	32.9	19.3
Cedar sawdust	752	32.5	4.2
Douglas-fir sawdust	996	30.3	13.8
Douglas-fir white rot	73	29.7	31.9
Hemlock sawdust	1157	26.5	14.7
Douglas-fir bark			
Young	306	26.2	8.6
Old	493	18.2	4.9
Chute mud	180	19.6	9.5
Douglas-fir red rot	49	4.8	1.4
Scholler lignin	881	4.3	3.5
Moss peat	58	3.6	1.0
Soil only (1.61% C)	12.2	2.4	1.8

Fig. 3.—Sunflowers grown on Chehalis silty clay loam soil with Douglas-fir sawdust incorporated. From left to right: (1) sawdust at 10 tons per acre (2,000,000 pounds soil), no nitrogen; (2) 10 T/A with ammonium nitrate to give C:N ratio of 50:1; (3) 10 T/A, C:N = 20:1; (4) 100 T/A, no N; (5) 100 T/A, C:N = 50:1.

Fig. 4.—Sunflowers grown on Chehalis silty clay loam soil with organic treatments at 10 T/A and ammonium nitrate to give C:N = 20:1. (1) Soil only with ammonium nitrate as with organic treatments; (2) Douglas-fir sawdust; (3) Ponderosa pine sawdust; (4) Douglas-fir bark, old; (5) Rye straw.

dust because the amount of ammonium nitrate required would prove toxic. Pine sawdust and bark without added nitrogen were strongly depressive. Ammonium nitrate supplements prevented these effects, and with 10-ton treatments gave increases significantly greater than those obtained with soil plus corresponding amounts of ammonium nitrate, but without the sawdust or bark.

Rye straw, due to its rapid decomposability, decreased yields to the greatest extent. Even with added nitrogen, no significant increases were obtained over the soil controls. These results indicate that sawdust and bark exert a slower if not a lesser nitrogen demand than straw when incorporated with the soil. Similar results have been obtained with mulches. Effects of some of these treatments on plant growth are shown in Figs. 3, 4, 5, and 6.

In field studies it has been found that, for blueberries, 4 to 6 inch mulches of sawdust and bark were much superior to mulches of oak leaves or grain straw and to clean cultivation (27). Blueberries respond particularly well to mulches because their fibrous, shallow root system is favored by a covering that retains moisture and yet permits air circulation.

The superior moisture-retaining properties of woody mulches compared to straw is shown in Table 8. This table also shows the much higher population of microorganisms, especially molds, that mulches harbor. The mulches were strongly acid, about pH 4.5, while the soil pH was 6.5. This accounts for low *Streptomyces* percentages and, in part, for high mold counts in the mulches.

A field experiment was carried out on the same soil type with strawberries in which 4 inches of Douglas-fir sawdust, approximately 80 tons (dry basis) per acre, was used as a mulch on some plots and incorporated to a depth of 8 inches on others. Results showed that, with or without nitrogen fertilizer treatment, the mulch increased yields while the incorporation had no significant effect (27). With other crops that have greater nitrogen requirements, about 100 pounds of nitrogen per acre inch of sawdust (20 tons), or 0.25 percent nitrogen by weight of sawdust, were needed to overcome the nitrogen-depressing effect during the first year. For the following 2 or 3 years, about one-half this amount of nitrogen was required. Other investigators have found that pine sawdust mulches increased yields of crops but that incorporated sawdust had no beneficial effect on plant growth (31). It has

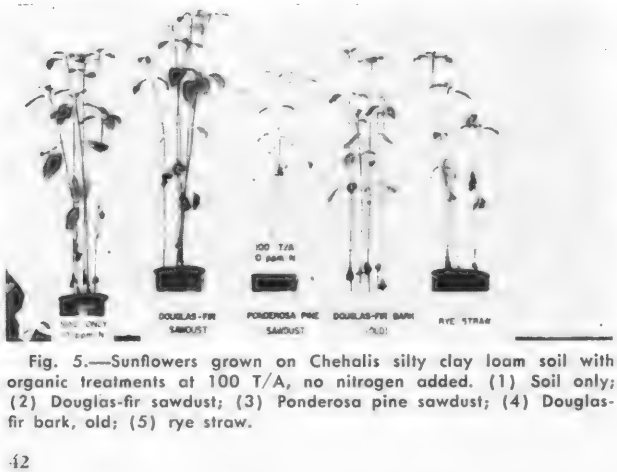


Fig. 5.—Sunflowers grown on Chehalis silty clay loam soil with organic treatments at 100 T/A, no nitrogen added. (1) Soil only; (2) Douglas-fir sawdust; (3) Ponderosa pine sawdust; (4) Douglas-fir bark, old; (5) rye straw.

Table 8.—MICROORGANISMS IN BLUEBERRY MULCHES[1] AND SOILS[2]

Kind of mulch	Moisture (dry basis)	Numbers per gram, dry basis		
			Bacteria	
	percent	Molds thousands	Total millions	Streptomyces percent
Alder sawdust	60	9200	2020	33
Soil below	19	19	24	70
Cedar tow	54	9200	366	21
Soil below	21	29	20	63
Douglas-fir bark	57	1360	18	33
Soil below	24	480	24	52
Wheat straw	35	560	900	16
Soil below	13	26	16	53
Clean cultivated	4	36	10	53

[1]3 years old; 6 inches deep, maintained by yearly applications; 100 lbs. NH_4 SO_4 acre/year. Sampled in early fall.
[2]Chehalis silty clay loam soil.

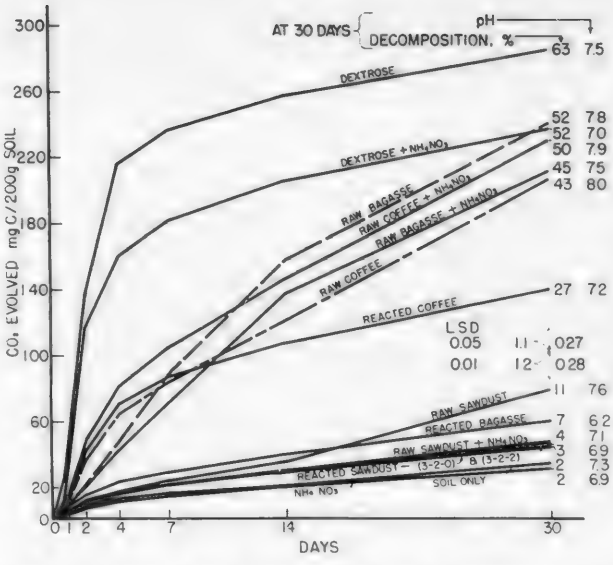


Fig. 7.—Carbon dioxide evolution as an index of decomposition of raw and reacted sawdust, bagasse and coffee grounds added to Salinas sandy loam soil at 2000 p.p.m. carbon.

Fig. 6.—Sunflowers grown on Chehalis silty clay loam soil with organic treatments at 100 T/A and ammonium nitrate to give C:N = 50:1. (1) Soil only with ammonium nitrate as with organic treatments; (2) Douglas-fir sawdust; (3) Ponderosa pine sawdust; (4) Douglas-fir bark, old; (5) rye straw.

been shown, however, that, although incorporated Douglas-fir and alder sawdust decreased nitrate and available phosphate, it increased organic matter and total nitrogen, improved soil aggregation, and increased useful moisture range (22).

While protective mulches are advantageous in conserving moisture, influencing temperature, controlling weeds, and keeping berries clean, they have the disadvantage of lowering soil temperature and favoring the incidence of red stele disease of strawberry in wet soil where the fungus pathogen is present (30). Results of some preliminary studies (2, 29) on incidence of red stele in infected soil mixed with Douglas-fir bark materials at 100 tons per acre are shown in Table 11. Three flats of 20 healthy strawberry plants for each test were prepared in October, 1957, watered in the greenhouse until November, then placed outdoors in cold frames until April, 1958. Plants were then removed and roots slit for detection of red stele disease. This was repeated the following year with the same soil-bark mixtures in flats except on fresh, healthy plants. Certain mixtures of soil and treated bark appeared to be quite effective in reducing the percentage infection, although as many as 25 percent of the plants died.

Further work is in progress to determine the chief factors involved in the suppression of red stele under the conditions studied. Simple hot water extraction of bark appeared to be particularly effective. While results the second year did not duplicate precisely those for the first year, it can be seen that the red stele infection in the control soil was less severe the second year.

Sawdust mulches one inch deep in various vegetable plots more than doubled yields and were better than black polyethylene film in experiments conducted by the New York Agricultural Experiment Station (26). Favorable results with sawdust in conjunction with adequate applications of nitrogen fertilizer have also been obtained elsewhere (1, 13, 24).

Farmers in the Bitteroot Valley and Flathead Region of Montana are now using sawdust almost to the limit of its availability, in many instances hauling it more than 50 miles. While much of it is used first in feed lots, which adds manurial value and causes primary decomposition, some is applied directly to fields, especially in the Flathead Lake area. These practices have been promoted during the past 10 years by the University of Montana School of Forestry, the U. S. Forest Service's Rocky Mountain Forest and Range Experiment Station, and by certain individuals in Vocational Agriculture and in the Soil Conservation Service.

Table 9.—EFFECT OF DOUGLAS-FIR BARK MATERIALS ON RED STELE DISEASE IN STRAWBERRIES (2, 27)

Soil-bark mixture[1]	Number of plants							
	Live		Diseased		Healthy		Red stele	
	1957–58	1958–59	1957–58	1958–59	1957–58	1958–59	1957–58 Percent	1958–59 Percent
Whole bark, untreated (0.18% N)	59	58	59	49	0	9	100	84
Ammoniated bark[2] (4.3% N)	58	46	34	14	24	32	57	30
Benzene-extracted whole bark (0.14% N)	60	58	58	32	2	26	97	55
Ammoniated benzene-extracted bark, (2.6% N)	47	56	8	30	39	26	17	54
Hot-water-extracted bark (0.17% N)	46	52	9	1	37	61	20	2
Ammoniated hot-water-extracted bark (3.0% N)	48	57	22	26	26	31	46	46
Control soil	59	56	59	51	0	5	100	91

[1]Bark materials mixed with a composite of several infected Willamette Valley soils at 100 tons per acre.
[2]Ammoniation of bark materials by treatment with ammonia at room temperature, excess ammonia removed by drying.

Processed Wood Wastes

Treatment of wood wastes by various means to increase their nitrogen content or to decrease their nitrogen demand when added to the soil is advantageous where intensive use can provide economic justification. Such treatments include chemical processing, suffusion with anhydrous or aqueous ammonia, mechanical mixing with nitrogen fertilizers, and composting.

Treatment of sawdust and other cellulosic wastes with dilute sulfuric acid at temperature near the charring point results in a decrease in hydrolyzable carbohydrates and an increase in non-hydrolyzable lignin or lignin-like substances (15). Such reacted sawdust and other reacted materials, due to conversion of much of the cellulose to resistant complexes, are less readily decomposable than are the raw materials. This decreases or eliminates the microbial demand for available nitrogen when such organic matter is added to the soil. It also imparts desirable lasting qualities and prolongs physical effects. Since, after the heat

treatment, ammonia is added to neutralize the acid, the processed material carries more than enough nitrogen for its own decomposition. Some of the nitrogen apparently is in organic combination. Use of phosphoric acid with the sulfuric in the primary treatment, or nutrient fortification of the product with mineral fertilizer, can enhance value and economic feasibility.

Sawdust and some agricultural wastes processed by a modified Fersolin process at the Pope and Talbot, Inc., Oakridge pilot plant have been investigated for their decomposability and nitrogen transformations in soil. The reacted products, especially bagasse and coffee, were rendered much more resistant (Fig. 7). Analysis of the reacted sawdust (2–3–0), fortified to some extent with ammonium nitrate and superphosphate, showed a total nitrogen content of 3.28 percent. Of this amount 23.7 percent was present as nitrate and 47.5 percent as ammonium distillable at pH 7.4, hence readily available. About 30 percent of the nitrogen was organically bound and more or less slowly available. When incubated with soil in the labatory, this organically bound nitrogen was completely ammonified and nitrified within 30 days. Thus the reacted product more than meets the nitrogen requirements of microorganisms involved in decomposition, and also provides both immediately available and relatively slowly available nitrogen for plant growth.

It is of interest to note that reacted spent coffee grounds contain 75 percent of the total nitrogen (4.3 percent) in slowly available organic combination. In this the product resembles a urea-form fertilizer such as Uramite or Nitroform, with a urea formaldehyde ratio of approximately 1.2:1.

Particle board waste, where available, can be used on the soil to advantage. Samples of raw chips from a Sweet Home, Oregon, plant were found to contain 0.084 percent nitrogen, giving a carbon-to-nitrogen ratio of 585, while the particle board waste analyzed 1.691 percent nitrogen and a ratio of 29.2. Since almost all the nitrogen in the waste is derived from the urea-formaldehyde bonding resin, it is gradually released in the soil. The waste induces no nitrogen deficiency, and supplies available nitrogen over a period of time for growing plants. It decomposes somewhat more rapidly than plain sawdust or raw chips. Greenhouse studies showed that particle board waste at 10 and 100 tons per acre significantly increased yields of sunflowers and gave better results than corresponding amounts of nitrogen as Uramite added with raw chips. With equivalents of ammonium nitrate, however, yields were considerably greater due to immediate availability of the nitrogen. Under practical conditions, particle board waste, plus N–P–K fertilizers, could prove quite useful.

A process for treating sawdust by pyrolysis has been invented by Camlind Research Co., San Anselmo, California for developing a "new and original soil conditioner". This is alleged to "break down unstable and toxic" components into more stable compounds that are non-toxic to plant life. With the possible exception of walnut and cedar (25), it is doubtful if raw sawdust or bark contains any substances that are directly toxic in the soil; in any case the "toxicity" is overcome by adequate use of nitrogen fertilizers. In effect, pyrolysis converts readily decomposable constituents into resistant forms and thus retards nitrogen demand when the product is applied to soils.

For a number of years, the Ivory Pine Company, Dinuba, California, has composted over 60 tons of granulated bark per day for farm, home and nursery use. The bark is treated in long windrows 5 by 20 by 200 feet by injecting aqueous ammonia (17). In about six months the mass becomes stabilized after a preliminary bacterial fermentation followed by mold action. The product has a carbon-to-nitrogen ratio of approximately 40:1, and is sold under the name "Forest Humus". In Oregon, a similar project with bark-sawdust mixtures is being developed by the Willamette Valley Lumber Company at Dallas and Carleton.

Sawdust and feed-pen manure are processed in a mechanical silo at Elgin, Oregon, to product about 50 tons of compost per day. This is used at 600 to 1000 pounds per acre by beet and hop growers in the area with good results. It analyzes slightly better than 1–1–1 (total nitrogen as N—available phosphorus as P_2O_5—water-soluble potassium as K_2O, in percent) and is sold as "Oregon Black Gold". A commercial inoculant was used at first, but subsequently has been found unnecessary.

A similar enterprise has been operating near Redmond, Oregon, for several years. In this case, sawdust and corral manure is composted in windrows and ACCO[3] inoculant is used. The compost contains about one percent nitrogen. It is characteristic of composts made with feed lot and corral manure in that they are high in ash, often 50 to 60 percent. The greater proportion of this ash is probably derived from soil or sand collected with the manure.

Various starters or inoculants for composting sawdust and other organic refuse appear on the market. Usually these are not required (19). The refuse is naturally inoculated, or if additional microorganisms are desired, they may be obtained from small applications of manure or fertile soil.

Wilde (32) has developed a mechanized method for composting sawdust in which an inoculum of the fungus *Coprinus ephemerus* is added after preliminary treatment with ammonia, phosphoric acid, and potassium sulfate. The compost action is completed in about four weeks. Cation exchange capacity of maple sawdust was greatly increased by composting with this fungus; percentage of nutrients was also increased (10). Composting wood waste with manures and other organic matter has been discussed by Dunn (12) and by Gessel (18).

The principles and economics of composting in general have been outlined in a report of the California Sanitary Engineering Research Project (8).

A Portland, Oregon, company mixes simples (nutrient bearing ingredients) with dry sawdust to make a 6–10–4 product sold under the brand name "Fertil-Mulch". A darkening agent is added to give a pleasing appearance.

Alder sawdust is often prized because it decomposes relatively rapidly. It has a more rapid but less prolonged nitrogen demand. At Eugene, Oregon, a small enterprise hammermills alder slabs and bark and adds a booster powder to produce "Forest Gold." It is of good appearance and free of splinters.

Specialized mill wastes can also be used on the soil. Fiberboard punchings are clean and easy to handle, but because they contain more cellulose and less lignin than does sawdust, more nitrogen should be added with them. Dehydrated ammonia-base waste sulfite liquor ("Orzan A") contains 3.5 percent nitrogen and 6.5 percent sulfur; about one-half of the nitrogen and 7 percent of the sulfur is readily available (4) and it can improve aggregation of certain soils (7).

Untreated sawdust and bark are often available in bag lots at various garden supply stores, and at relatively high cost. Three large mills at Medford, Oregon, now grind all their waste bark and sell it for horticultural purposes in the vicinity. Dwyer Fuel Company markets "Barkdust" in the Portland area. The product consists of fir and hemlock bark that has been ground and screened through a ⅜-inch mesh. Demand by local nurserymen and landscapers exceeds production facilities.

Old rotten sawdust is preferred for home garden use. Not only does it

[3] Arizona Compost Co., Phoenix, Arizona.

have a pleasing appearance, but as a result of partial decomposition, its readily decomposable components have been destroyed or stabilized so that the carbon-to-nitrogen ratio has narrowed and the nitrogen demand has become less. Weathered sawdust (Table 2) approaches these characteristics. Supplies of well-rotted sawdust are quite limited.

In this connection, a warning should be sounded. A dark-colored sawdust produced within a relatively new large pile is not a well-rotted sawdust. It is somewhat charred from an anaerobic fermentation induced by compaction under moist conditions. Effective insulation by the outer layer confines the heat of fermentation to such an extent that charring may occur. In some cases, spontaneous combustion results. Brown to black sawdust formed in this way becomes supersaturated with volatile organic acids and other fermentation products. It has a sharp, acid, and molasses-like odor; fumes from a freshly exposed mass are strongly irritating. If such "hot" sawdust is placed on lawns or around plants or shrubs, the volatile fumes may prove destructive. Leaves turn yellow and the plants may die. Grass usually recovers and generally only the lower branches of shrubs are affected. Sawdust of this nature should be avoided. It is extremely acid, (pH near 2) and requires as much as 500 pounds of limestone per ton for neutralization. In greenhouse trials with one inch mulches it was found extremely toxic, but a sample previously thoroughly leached with water promoted as good or better growth of tomatoes, cabbage, and onions as did either fresh or old sawdust. At least a year of weathering in a thin layer would be required to dissipate the acidity.

Ammoniated Bark

Ground bark recently has received much attention for mulching purposes and soil conditioning. It has a pleasing color, high moisture capacity, and is long lasting. However, barks containing small, loosely-held fibers, as in the case of Douglas-fir bark, are somewhat disagreeable to handle.

Fig. 8.—Pilot plant for ammoniation of Douglas-fir bark.

The presence of reactive substances, including polymeric phenolic acids, in bark renders it susceptible to many chemical reactions. For studies on decomposition and nitrogen availability in bark fortified with nitrogen, the Oregon Forest Products Laboratory treated ground Douglas-fir bark with anhydrous ammonia at ambient temperatures in a pilot-plant apparatus consisting of three inclined screw conveyors in series (Fig. 8). The bark had a moisture content of 25 percent, and the particle size distribution is shown in Table 1. The amount of ammonia that reacted chemically with the bark was regulated by the rate of bark travel as determined by the speed of the inclined screw augers, and by rate of ammonia flow. Excess ammonia was removed by drying at 93° C for 24 hours. Analytical data for several of the products are shown in Table 10. The major portion of the nitrogen was found to be firmly bonded to bark constituents; the specific nature of this bonding is under study at the Oregon Forest Research Center.

Soil respiration studies (2) indicated that the ammoniated bark was slightly more resistant than plain bark to decomposition in Willamette silty clay loam soil. Some of the nitrogen was rather rapidly liberated as ammonia by microbial action, however. This process whereby organic nitrogenous substances are decomposed to ammonia, carbon dioxide, and water is termed "ammonification", and is to be distinguished from "ammoniation" or the chemical introduction of ammonia. The bark with 1.68 percent nitrogen was 25 percent ammonified in six days. With increasing nitrogen content, the percentage ammonified was correspondingly decreased, which indicates that the additional nitrogen introduced became more slowly available. Bark containing 4.27 percent nitrogen was only 11 percent ammonified in the same period. The control bark (0.15 percent N) caused a net decrease in ammonia and nitrate in the soil to assimilation by microorganisms active in the decomposition.

Greenhouse pot studies on availability of nitrogen in the various bark products mixed with the soil at the rate of 10 tons per acre for growth of three successive crops of sunflowers indicated that only part of the nitrogen introduced by ammoniation was available for the first crop. About one-half remained at the end of the first crop after three months. For the third crop, however, slightly more nitrogen was available than with ammonium nitrate. In the latter case, the ammonium nitrate was evidently exhausted by the

Table 10.—ANALYSIS OF AMMONIATED DOUGLAS-FIR BARK (2)

Material	Kjeldahl nitrogen Percent	Total carbon Percent	C/N ratio	NH_4^+ = nitrogen Distilled at pH 7.4 ppm	NH_4^+ = nitrogen Distilled at pH 11.5 ppm	pH	Water-holding capacity Percent
Original bark	0.16	53.81	347	45	70	4.2	320
Ammoniated bark, #1	1.68	53.68	32	536	6595	6.3	229
Ammoniated bark, #2	2.83	54.13	19	1043	9325	6.4	193
Ammoniated bark, #3	3.71	55.94	15	2644	3197	5.9	188
Ammoniated bark, #4	4.27	56.05	13	3816	4940	6.4	179
Soil[1]	0.18	2.69	15	25	95	5.8	68

[1]Willamette silty clay loam.

first crop, which was always greater with equivalent supplemental nitrogen in this form. All the ammoniated barks gave significant increases in yields of the first crop (Table 11). These results indicate that ammoniated bark can be used on the soil without inducing nitrogen starvation, and that it can supply both readily available and slowly available nitrogen. The soil used for this experiment had good chemical and physical characteristics; this could have limited the benefits derived from physical and other properties of the bark, which on a poorer soil might be more effective.

Table 11.—EFFECT OF DOUGLAS-FIR BARK, AMMONIATED BARK AND AMMONIUM NITRATE ON SUNFLOWER YIELDS IN GREENHOUSE POTS. WILLAMETTE SILTY CLAY LOAM SOIL. BARK ADDITIONS AT 10 TONS PER ACRE, OR 1%. (2)

Treatment	Total nitrogen[2]	Dry weight			
		1st crop	2nd crop[2]	3rd crop	Total
	ppm	g	g	g	g
Soil only	1800	8.7	2.5	10.7	21.6
NH_4NO_3, 253 p.p.m.[1]	2053	34.7	2.2	10.3	47.2
Bark (0.16% N)	1816	9.7	2.3	8.3	20.3
Bark + NH_4NO_3 = 1.68% N	1968	24.7	2.3	7.0	34.0
Bark + NH_4NO_3, C/N = 20:1	2069	35.3	2.0	7.0	44.3
Ammoniated bark:					
#1, 1.68% N	1968	16.3	2.2	8.7	27.2
#1 + NH_4NO_3, C/N = 20:1	2068	26.3	2.2	9.7	38.2
#2, 2.83% N	2083	20.0	2.2	8.3	30.5
#3, 3.71% N	2171	15.7	2.3	9.7	27.7
#4, 4.27% N	2227	18.7	2.0	11.0	31.7
L.S.D. 0.05		2.9	0.6	1.7	

[1]Average of rates to adjust C/N ratios to 20:1.
[2]In soil plus additions.
[3]Low yields due to winter season.

Conclusion

The use of wood residues for soil improvement is gaining wider acceptance and providing more utilization of wood wastes.

In evaluation of residues for suitability as mulches or soil conditioners, it is important to determine particle-size distribution, carbon-to-nitrogen ratio, availability of nitrogen, composition of residues, rate of decomposition, and influence on plant growth.

Sawdust and related materials have essentially no fertilizer value; for soft woods their analysis averages 0.1–0.03–0.10 for N–P_2O_5–K_2O. For reacted or fortified products, the fertilizer value is commensurate with their added nutrient content. When purchased at a price above that for which the same nutrients could be obtained in mineral fertilizers, the additional cost represents a premium paid for the organic matter and its potential effects on humus supply, physical factors, and possible intangibles. All these properties are important, however, and sawdust and other wood wastes should go back to the soil within the limits of feasibility.

Literature Cited

1. Allison, F. E., and M. S. Anderson. 1951. The use of sawdust for mulches aid soil improvement. U. S. Dept. Agr. Circ. 891.
2. Aspitarte, T. R. 1958. Availability of nitrogen in ammoniated bark used as a soil amendment. Doctoral thesis, Oregon State College, Corvallis.
3. Bollen, W. B. 1953. Mulches and soil conditioners: carbon and nitrogen in farm and forest products. Agr. Food Chem. 1: 379–381.
4. Bollen, W. B. 1955. Microbial transformations and effects of dehydrated ammonia-base sulfite spent liquor in soils. Tappi 38: 208–215.
5. Bollen, W. B. 1959. Microorganisms and soil fertility. Oregon State Monographs. Studiese in Bacteriology, No. 1.
6. Bollen, W. B., and K. C. Lu. 1957. Effect of Douglas fir sawdust mulches and incorporations on soil microbial activities and plant growth. Soil Sci. Soc. Amer. Proc. 21: 35–41.
7. Bollen, W. B., A. N. Roberts, and E. Hansen. 1955. Effect of Orzan–A, a dehydrated ammonia-base waste sulfite liquor on microorganisms, soils, plants. Oregon Agr. Exp. Sta. Misc. Paper 12.
8. California University–Berkeley. 1950. Composing for disposal of organic refuse. Tech. Bul. No. 11, Sanitary Enineering Research Project.
9. Clark, K. G., J. Y. Yee, V. L. Gaddy, and F. O. Lundstrom. 1956. Solubility relationships and nitrification characteristics of urea-form. J. Agr. Food Chem. 4: 135–140.
10. Davey, C. B. 1953. Sawdust composts: their preparation and effect on plant growth. Soil Sci. Soc. Amer. Proc. 17: 59–60.
11. Dunn, S. 1956. The influence of waste bark on plant growth. N. H. Agr. Exp. Sta. Bul. 435.
12. Dunn, S., and J. D. Emery. 1959. Wood wastes in composts. Forest Prod. J. 9: 277–281.
13. Dunn, S., L. P. Wolfe, Jr., W. A. Macdonald, and J. R. Baker. 1952. Field plot studies with sawdust for soil improvement. Plant and Soil 4: 164–170.
14. Farber, B. 1951. U. S. Patent No. 2,574,027.
15. Farber, E. 1952. Condensation and hydration reactions with low-grade cellulosic materials. Tappi 35(1)): 126A-128A.
16. Farber, E., and R. R. Hind. 1959. Process for converting sawdust into fertilizer. Forest Prod. J. 9: 340–343.
17. Field, P. 1958. Residues from the sawmill . . . making smoke or profit? Forest Prod. J. 8(11): 27A–30A.
18. Gessel, S. P. 1959. Composts and mulches from wood wastes. New Wood-Use Series, Cir. 33. Univ. of Wash., Seattle.
19. Golueke, C. G., B. J. Card, P. H. McGauhey, 1954. A critical evaluation of inoculums in composting. Applied Microbiol. 2: 45–53.
20. Hallam, M. J., and W. V. Bartholomew, 1953. Influence of rate of plant residue addition in accelerating the decomposition of soil organic matter. Soil Sci. Soc. Amer. Proc. 17: 365–368.
21. I/EC Reports. J. S. 1960. Fertilizer from sawdust. Indus. Eng. Chem. 52: 30A–34A.
22. Kirsch, R. K. 1959. Effects of sawdust mulches. I. Soil properties. Oreg. Agr. Exp. Sta. Tech. Bul. 49.
23. Kurth, E. F., and J. E. Smith, 1954. The chemical nature of the lignin of Douglas-fir bark. Pulp and Paper Mag. of Canada, 55: 125–132.
24. Lunt, H. A. 1955. The use of woodchips and other wood fragments as soil amendments. Conn. Agr. Exp. Sta. Bul. 593.
25. Lunt, O. R., and B. Clark, 1959. Horticultural applications for bark and wood fragments. Forest Prod. J. 9: 39A–42A.
26. Pratt, A. J., and S. Comstock, 1958. Mulches or cultivation for vegetable crops? Farm Research, 4–5. Jan.
27. Roberts, A. N., and W. M. Mellenthin, 1959. Effects of sawdust mulches. II. Horticultural crops. Oreg. Agr. Exp. Sta. Tech. Bul. 50.
28. Prianishnikov, D. N. 1951. Nitrogen in the life of plants. Translated by S. A. Wilde. Kramer Business Service. Madison, Wis.
29. Vaughan, E. K. 1959. Unpublished data. Botany Department, Oregon Agr. Expt. Station.
30. Vaughan, E. K., A. N. Roberts, and W. M. Mellenthin, 1954. The influence of Douglas fir sawdust and certain fertilizer elements on the incidence of red-stele disease of strawberry. Phytopathology 44: 601–603.
31. White, A. W. Jr., J. E. Giddens, and H. D. Morris, 1959. The effect of sawdust on crop growth and physical and biological properties of Cecil soil. Soil Sci. Soc. Amer. Proc. 23: 365–368.
32. Wilde, S. A. 1958. Marketable sawdust composts: their preparation and fertilizing value. Forest Prod. J. 8(11): 323–326.

Discussion

Question: What about kiln dried wastes?

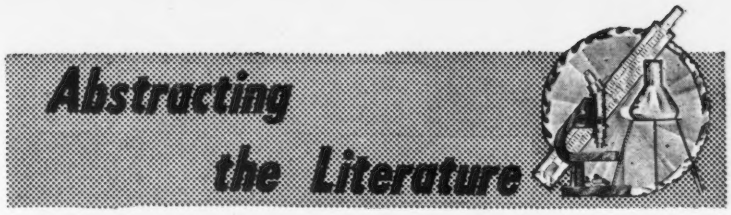
Answer: In general, there should be a smaller rate of decomposition. There is some cross linking of cellulose material resulting in an irreversible change that would tend to increase resistance.

Question: Would fines accelerate the process?

Answer: Yes. Because of their greater surface exposure, fines would decompose in a shorter time than coarse material, unless compaction should reduce aeration.

Question: Can the salt effect of heavy applications of nitrogen sources be avoided by incremental additions?

Answer: Yes. It is necessary to do this for heavy treatments of sawdust, like 50 to 100 tons per acre. In such cases the plants should be observed for nitrogen starvation symptoms (yellowing), and the increments added as required.



NAVAL STORES

Nikolaev, I. F., Sinelobov, M. A., Sukhov, G. V., Timofeev, M. P., and Toburdanovskiĭ, A. N. A tree tapping method with sulfuric acid, involving simultaneous incisions. Gidroliz. i Lesokhim. Prom. 12, no. 6: 11 (1959). [Russ.]

The method described involves making several parallel cuts simult. at the beginning of the tapping season, then applg. sulfuric acid (in the form of a liquid or paste) to the individual cuts at definite time intervals, starting with the uppermost cut. Tests in exptl. pine stands showed that this method of tapping does not reduce the resin yield and results in considerable labor savings by eliminating the need for carrying the cumbersome cutting equipment every time the resin is collected. (A.B.I.P.C. 31:4)

CHIP PIPELINES

Elliott, D. R. The transportation of pulpwood chips in pipelines. Pulp Paper Mag. Can. 61, no. 5: 170–2, 174–5 (May, 1960). See also For. Prod. Jour., no. 8: 419–22 (Aug., 1960).

A preliminary rept. on a study of the transportation of pulpwood chips in pipelines is presented. The over-all conclusions of the study were: chip deterioration is not a drawback to the operation of pulpwood chip pipelines; mixts. contg. 30% solid wood by vol. can be handled; and friction losses and power requirements for mixts. are likely to be very close to those for water alone. An appln. of the pipeline in the woods is considered, and calcns. given for detg. the required capacity of the pipelines—main, feeder, and branch; power requirements; investment; and operating costs. (A.B.I.P.C. 31:4)

WOOD MEAL

Anon. Wood meal as polishing agent, filler, etc. Adhäsion 4, no. 9: 471–2 (Sept., 1960). [Ger.]

Wood meal is mfd. by comminuting sawdust, planer shavings, and other small wood-waste particles to a size of 1.5–4.0 mm., followed by grinding (defibration), screening, drying, and packing in paper bags. Stone grinders are usually preferred to disk refiners or hammer mills in order to retain the fibrous (micellar) structure of the wood. The final prod. should contain less than 5–6% moisture (8% max.) and less than 3–4% resin. Among hardwoods, beech is preferred. Cork and hemp are not equiv. substitutes for wood meal. Coarse wood meal is used in linoleums and magnesite boards, whereas better qualities are used as fillers for synt. resins and plastics. Other filler applns. include dynamite, insecticides, soap powders, rubber, CN-base adhesives, and so-called plastic wood. (A.B.I.P.C. 31:4)

WOOD RADIOLYSIS

Freĭdin, A. S., Malinskiĭ, Yu. M., and Karpov, V. L. The effect of ionizing radiations on the chemical resistance of wood. Gidroliz. i Lesokhim. Prom. 12, no. 4: 4–7 (1959). [Russ.] *cf.* A.B.I.P.C. 30: 69.

Samples of pine sapwood were irradiated with γ-rays from cobalt-60 sources having an intensity of 600, 1400, and 20,000 g.-eq. of radium. The samples received total doses of up to 500×10^6 rep at a rate of 220 rep/sec. Chem. studies of the irradiated wood showed that the irradiation effects are detd. by the flg. factors: the total dose, irradiation intensity, and the conditions under which irradiation is carried out (humidity, temp., presence of oxygen and other agents). In the carbohydrate-lignin complex, irradiation damage involves mainly the carbohydrate moiety. Lignin is considerably more resistant and is only partially solubilized, even at high irradiation doses. The carbohydrates are converted into water-sol. prods. with a high content of monoses. As a result, the wood polysaccharide fraction hydrolyzed by dil. hydrochloric and concd. sulfuric acids decreases. The solubilization of carbohyrates involves mainly the hemicellulose fraction, cellulose being considerably more resistant to irradiation. Irradiation is accompanied by oxidn. processes, particularly in the presence of oxygen. Irradiation in vacuum reduces the degradation of cellulose. The increase in the hydrolyzability of wood by irradiation suggests the possibility of using irradiated wood in the hydrolysis ind., particularly for the saccharification of matls. rich in pentosans. Irradiated wood also has other interesting possibilities: A matl. having a high mech. strength and chem. resistance was obtained by impregnation of irradiated wood with a monomer (such as styrol) and its subsequent noncatalytic polymerization. Wood radiolysis prods. might be utilized as animal feed. 10 ref. (A.B.I.P.C. 31:4)

TENSION WOOD

Siebers, A. M. The detection of tension wood with fluorescent dyes. Stain Technol. 35, no. 5: 247–51 (Sept., 1960).

Sections of a thickness of 15 μ cut from unfixed matl. by means of a freezing microtone were trd. for 1 hr. with 0.2% aq. solns. of a no. of fluorochromes. Under normal microscopical conditions no uniform staining pattern could be observed. With the aid of an UV microscope, however, one type of fluorescence pattern became apparent. In all cases observed the thickened gelatinous secondary cell walls of tension wood showed a remarkable lack of fluorescence; this is in marked contrast with the distinct fluorescence exhibited by the primary cell wall and by both primary and secondary cell walls of normal wood. 10 ref. (A.B.I.P.C. 31:4)

HYDROLYSIS LIGNIN

Vanina, V. I., Gutman, A. M., Zakoshchikov, A. P., Zakoshchikov, S. A., and Rotleider, B. M. Hydrolysis lignin as an active filler for polyvinyl chloride resin and microporous rubbers. Gidroliz. i Lesokhim. Prom. 12, no. 5: 8–9 (1959). [Russ.]

Hydrolysis lignin trd. with a mineral acid soln. (sulfuric, hydrochloric or phosphoric), then washed and dried, does not adsorb acids from dil. solns., but its adsorption capacity for inorg. and org. bases becomes as high as that of cellulose, and for alkali even higher than that of cellulose. Such a lignin adsorbs as much moisture as does cellulose and can be dyed with substantive and basic dyes. Lignin which has adsorbed 1.5–2% of a dye, such as malachite green or methylene blue, acquires a uniform and water-resistant color. Trmt. of lignin with an azotol (a cpd. which can be coupled with a diazo cpd.), such as β-naphthol, and then with a diazotized aromatic amine, such as ρ-nitroaniline, results in the formation of insol. azo dyes on its surface. Since lignin contains aromatic nuclei, it can be used as a component of azo dyes. The presence of dye mols. on the surface of lignin affects its adsorption capacity for alkali and its moisture obsorption. Methylene blue increases the alkali adsorption, whereas insol. azo dyes lower it. The moisture absorption is increased by azo dyes. When dyed lignin is added to PVC resin (20% on the basis of resin wt.), it becomes uniformly dispersed and acts as an addnl. plasticizer. Dyed lignin can replace 50% of powdered silica gel in the mfr. of microporous rubbers. As a substitute for silica gel, dyed lignin is considerably better than kaolin. (A.B.I.P.C. 31:4)

FIBERBOARD

Geddes, J. W., and Perot, J. J. Factors affecting the wrapping of fiberboard roof insulation. Tappi 43, no. 8: 720–2 (Aug., 1960).

Fiberboard is used extensively as insulation applied over steel, poured gypsum, and other types of concrete roof decks. If the matl. warps or buckles, severe problems are created for the applicator of the built-up roofing used in this type of construction. Warping is directly related to the moisture content of the fiberboard insulation, its color, and to the time of exposure. Warping decreases (at the same moisture content) as thickness increases. Warping is caused by a moisture gradient between the upper and lower surfaces of the insulation. Migration of moisture from the warmer upper face to the cooler lower face, plus loss of moisture to the air from the upper surface, causes expansion of the surface, and warping. No significant differences in warping tendencies were noted among a series of com. available prods., indicating that the type of fiber, pulping processes, and sheet formation are not major factors in this problem. In com. practice, difficulties can be eliminated by mfg. the matl. with low moisture content, observing proper shipping and storing procedures, and following recommended appln. procedures, incl. prompt appln. of the built-up roof. (A.B.I.P.C. 31:4)

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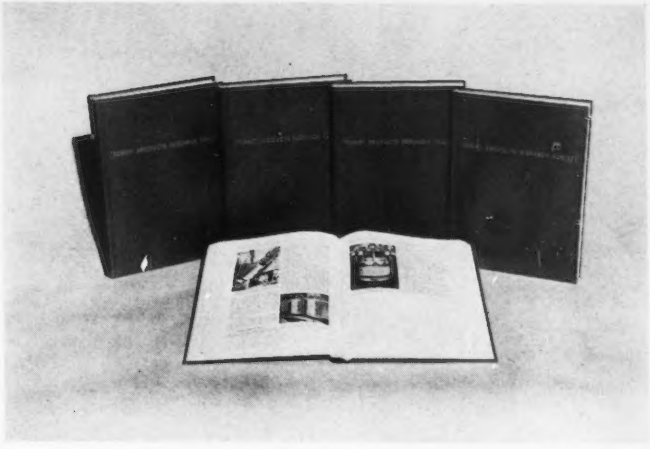

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1947—Vol. 1—UTILIZATION, ENGINEERING, PRESERVATION, SEASONING. 25 papers, 344 pp.

Articles cover: whole wood fiber manufacture; lignin chemistry; processing pine gum; paper and plastic overlays for veneer and plywood; integrated utilization; trends in logging; pulpwood logging developments in eastern Canada; building codes in postwar wood construction; engineering problems in prefabricated homes; postwar packaging field; functional furniture; postwar woodworking glues; metal to wood bonding; high frequency in woodworking; wood finishing; the use of car treated lumber; fence posts; an untapped market for the wood preserver; acid-proofing of wood; the artificial seasoning of wood in vapor of organic chemicals; kiln design; tungsten carbide developments; and tight cooperage plywood.

1948—Vol. II—UTILIZATION, FIBER PRODUCTS, BARKING, FINISHES, MACHINERY, R. F. HEATING. 50 papers, 500 pp.

Articles cover: economics of wood-waste utilization; losses in Redwood logging; small log gang sawmill; utilization of low-grade hardwood lumber; wood-distillation industry; sawdust carbonization; animal feeds from wood residue; small wood briquetting machine; special machines for utilization of waste slabs for glued core stock; interior trim from wood waste; wood-fiber production with revolving disk mills; effect of some manufacturing variables on the properties of fiberboard prepared from milled Douglas-Fir; small hydraulic log barker; mechanical methods of bark removal; studies on the chemical composition of bark and its utilization for structural boards; research in industry laboratories; history of furniture finishes; finishes resistant to alcohols and acids; low-bake synthetic finishes; simple testing methods for finishers; planning floor space for woodworking equipment; maintenance and operating practice for tungsten carbide tools.

1949—Vol. III—RAW MATERIAL, FURNITURE, PLYWOOD, UTILIZATION, GLUES, SEASONING. 55 papers, 607 pp.

Articles cover: more wood per acre; integrated wood utilization at Crossett; harvesting sawlogs; portable wood chippers; wood fibers from veneer waste; small permanent-type sawmills in better forest utilizatiton; pulpwood handling in the Lake States; tropical wood research for the furniture industry; effect of plywood glue lines on the accuracy of moisture-meter indications; No. 3 common Northern hardwood lumber for mechanized processing into glued products; cut stock from western softwoods; assembly material in furniture manufacture; supplementing wood with metal in furniture manufacturing; extending hot press urea resin with wheat and rye flour; furniture finishes; lumber core panels; rotary veneer cutting; molding plywood; insert-point circular headsaws; ills besetting the furniture industry; utilization of Redwood bark; utilization of waste sulfite liquor in concrete; semichemical pulping; dry-formed boards bonded with resins; wood, plywood and hardboard; compreg-resin-treated densified wood; wood preservatives; wood boring beetles; ignition temperatures of fireproofed wood, untreated sound wood, and untreated decayed wood; wood waste disposal and air pollution control in the Los Angeles area; pulp mill pollution; chemical composition of Ponderosa and Sugar Pine barks; lumber recovery from Douglas-Fir logs in British Columbia; resin adhesives; development of working stresses for stress-grade lumber; design and performance of laminated wood trusses, glued laminated wood, glued laminated Wej-weld frames; radio frequency heating.

1950—Vol. IV—MILLING, CONTAINERS, QUALITY CONTROL, PLYWOOD. 45 papers, 506 pp.

Articles cover: quality of second growth Douglas Fir; grading problems; quality control and the improved seasoning processes of the Redwood industry; saw teeth in action; lumber research to meet modern competition; hardwood log grading; recent developments in wirebound containers; method of utilizing and fabricating waste lumber; tests of strapped and lightweight lettuce crates; recent developments in containers; papermaking fibrous raw materials; utilization of low-grade hardwoods and softwoods; relation between wood and pulp properties; power vs. hand falling and bucking in logging operations; handling pulpwood; quality control in sawmill operations; hardwood plywood quality control; quality control in furniture production; defect detection equpiment non-destructive testing.

1951—Vol. V—MILLING, MACHINING, PRESERVATION, UTILIZATION, GLUES, KILN DRYING. 51 papers, 400 pp.

Articles cover: circular sawmills in the Tennessee Valley region; quality control in lumber manufacture, gangsaws in the manufacture of southern pine lumber; tropical hardwood production, logging and military equipment availability; defense and the availability of woodworking equipment; the importance of wood in the mobilization program; mobilization requirements for technical men in the woodworking industry; lumber conservation in military procurement and container design; military requirements for wood in packaging; wood requirements for specialized military uses; the place of small business in the military procurement program; marine laminating; selecting White Oak for bending lumber; machinability studies; carbide cutting tools in the wood industry; carbides; fire retardant treated lumber; wood preservation with particular reference to creosote; what the furniture industry expects from college-trained men; the scope and objectives of college training; graduate training in forest products technology.

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